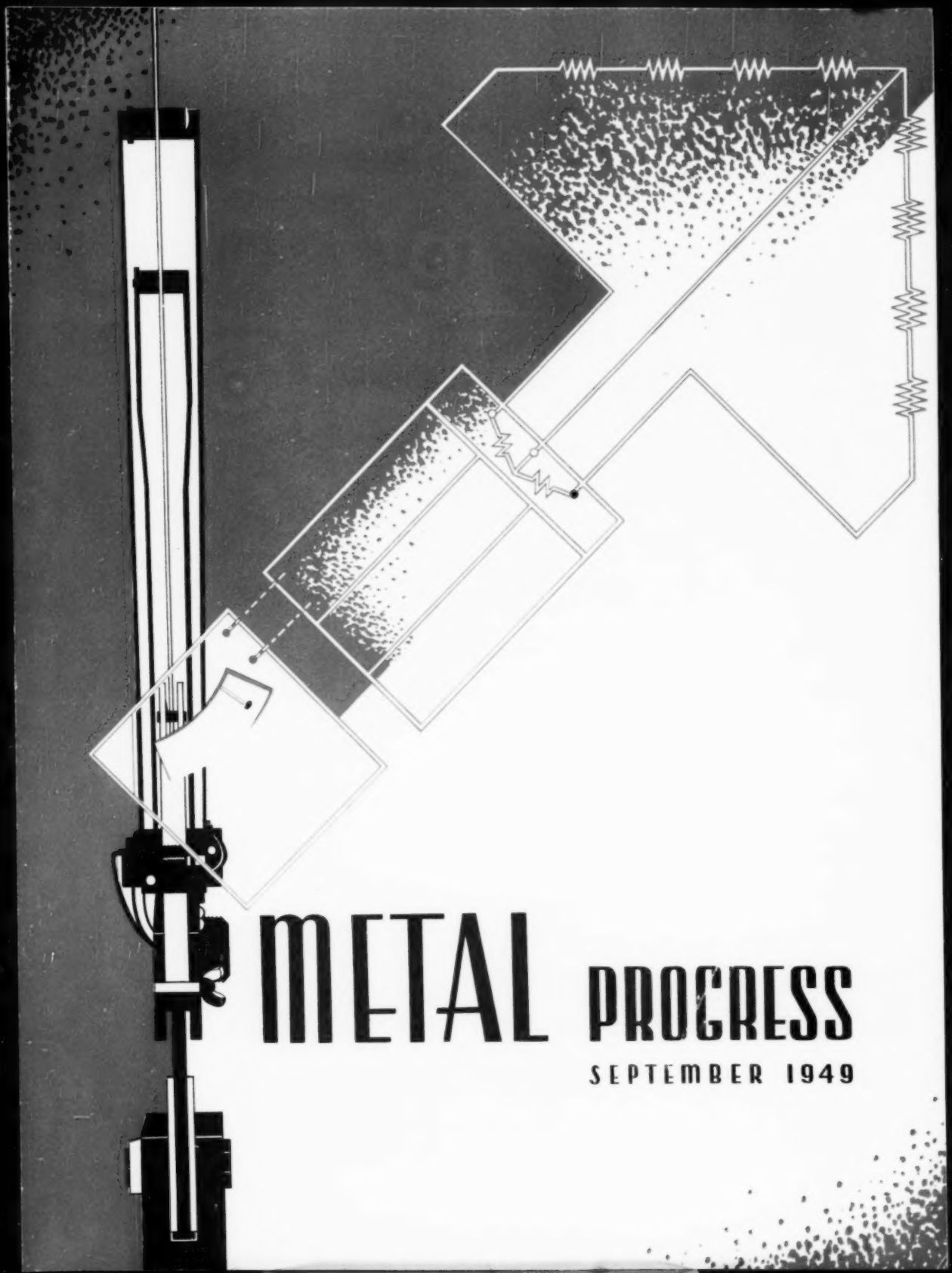


METAL PROGRESS

SEPTEMBER 1949

AN IMPORTANT MESSAGE TO METAL WORKERS INTERESTED IN:

SPINNING, BLANKING, STAMPING, MACHINING, ETC.

1. FORM THIN SECTION PARTS OF **LOW CARBON STEEL**
2. HEAT TREAT FORMED PARTS TO INCREASE CARBON TO A **MEDIUM OR HIGH CARBON STEEL**

A *New* HEAT TREATMENT

Homogeneous Carburization

Broadens the Scope of Production of Small Metal Parts

In homogeneous carburization the carbon content is built up throughout the entire thickness of the steel. The carbon potential of the prepared gas atmosphere is adjusted equal to the carbon desired in the steel. Then the low carbon steel is heated in this atmosphere where the carbon content gradually raises until the equilibrium is established between the atmosphere and the steel being treated.

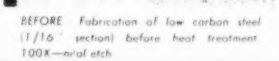
RX Gas Atmosphere

A 'Surface' RX Gas atmosphere is used for the process. 'Surface' RX Gas generators have been used extensively in industry for gas carburizing, dry cyaniding, carbon restoration, and clean hardening. They have proved most satisfactory in operation since they maintain an output of prepared gas atmosphere of constant analysis with a minimum of adjustment and maintenance.

THE PROCESS:

Homogeneous carburization permits the transformation of a low carbon steel into a medium or high carbon steel, in parts of thin section, after fabrication, and oftimes during the final step of heating for hardening.

BEFORE Fabrication of low carbon steel (1/16" section) before heat treatment. 100X—nital etch.



AFTER 1/16" section homogeneous carburized throughout at 1700°F in RX Gas atmosphere with a 0.60% carbon potential. Oil quenched. 100X—nital etch.

Continuous or Batch Type Furnaces

Either continuous or batch type furnaces can be used that have a heating chamber suitable for complete exclusion of both air and flue gas. Modern 'Surface' radiant tube heated furnaces, which have the necessary safeguards for good atmosphere control, are most applicable to this new process.

'Surface' Research and Development

The principles of carbon balance which have been so well applied to 'Surface' gas carburizing to permit control of surface carbon concentration, regardless of case depths, have been just as satisfactory adapted to homogeneous carburization at any desired carbon level from low and medium carbon to 1.00% carbon and higher if required.

WRITE FOR COMPLETE DETAILS... NO OBLIGATION

SURFACE COMBUSTION CORPORATION • TOLEDO 1, OHIO

'Surface' INDUSTRIAL FURNACES

This TOCCO gear machine is powered by a 150 K.W., 10,000 cycle motor-generator set. Photo—courtesy of International Harvester Company.

$82,507 Per Year with TOCCO* Induction Hardening

GEARS, shafts, pins, wheels, tubes and bars—almost any size or shape of part—or any metal, too—is adaptable to TOCCO hardening, brazing, annealing or heating for forging.

PRODUCTION UP—Engineers at the Milwaukee Works of International Harvester Company have adopted TOCCO for hardening final drive gears for famous International Harvester farm tractors. TOCCO increases production on the gear shown here from 14 to 35 per hour, 250% faster than conventional heating method, reduces job from a 3 shift to 2 shift operation, even with increased production schedule. Heating time is 35 seconds; oil quench, 60 seconds.

COSTS DOWN—TOCCO cuts cost—saves $82,507 per year on application shown above. TOCCO makes possible use of C-1050 A.R.R. steel instead of expensive A-8645-H alloy steel previously required. TOCCO also eliminates shot-blast, formerly needed to remove scale, and extra machining operations that used to be necessary to compensate for distortion.

Gear shown is 18½" O.D., width of face is 2", weight 34 pounds, 73 teeth. Hardness obtained is 55-66 R.C_e, using 140 K.W. of 10,000 cycle power.

Our Engineers can probably find applications in your plant where TOCCO can increase output and reduce unit costs.

THE OHIO CRANKSHAFT COMPANY

TOCCO

Mail Coupon Today

NEW FREE BULLETIN

THE OHIO CRANKSHAFT CO.
Dept. R-9, Cleveland 1, Ohio

Please send copy of "Typical Results of TOCCO Induction Heating for Forming and Forging".

Name _____
Position _____
Company _____
Address _____
City _____ Zone ____ State ____

	Machinability	Hobability	Core Strength	Wear Resistance	Distortion in Hardening	Pressure and Temperature
DURAMOLD C water-hardening, hobbing	POOR	BEST	POOR	GOOD	FAIR	LOW to MEDIUM
DURAMOLD B oil-hardening, hobbing	POOR	BEST	FAIR	GOOD	GOOD	LOW to MEDIUM
DURAMOLD A air-hardening, hobbing	*POOR	†GOOD	GOOD	GOOD	BEST	MEDIUM to HIGH
MULTIMOLD for machined molds, heat-treated or carburized	BEST	FAIR	FAIR	**FAIR	FAIR	MEDIUM
BTR oil-hardening, for machined molds	GOOD	FAIR	GOOD	GOOD	GOOD	HIGH
A-H5 air-hardening, for machined molds	FAIR	POOR	BEST	GOOD	BEST	HIGH

* Best, when annealed for machining
† Fair, when annealed for machining
** Good, when carburized and hardened

START WITH THE RIGHT MOLD STEEL

In selecting tool steel for plastic molds the first step is to answer these questions:

1. Is the mold to be cold-hobbed or machined?
2. Is high wear-resistance important? Short or long runs?
3. What core-strength is required?
4. How much distortion in heat-treatment is permissible?
5. High or low operating temperatures? How much pressure?

As a further aid in making the best choice, refer to the chart above. This is a general guide to six of our popular mold steels. Each is scrupulously inspected to assure the sound, clean surface and properly-annealed structure necessary for highly-polished cavities.

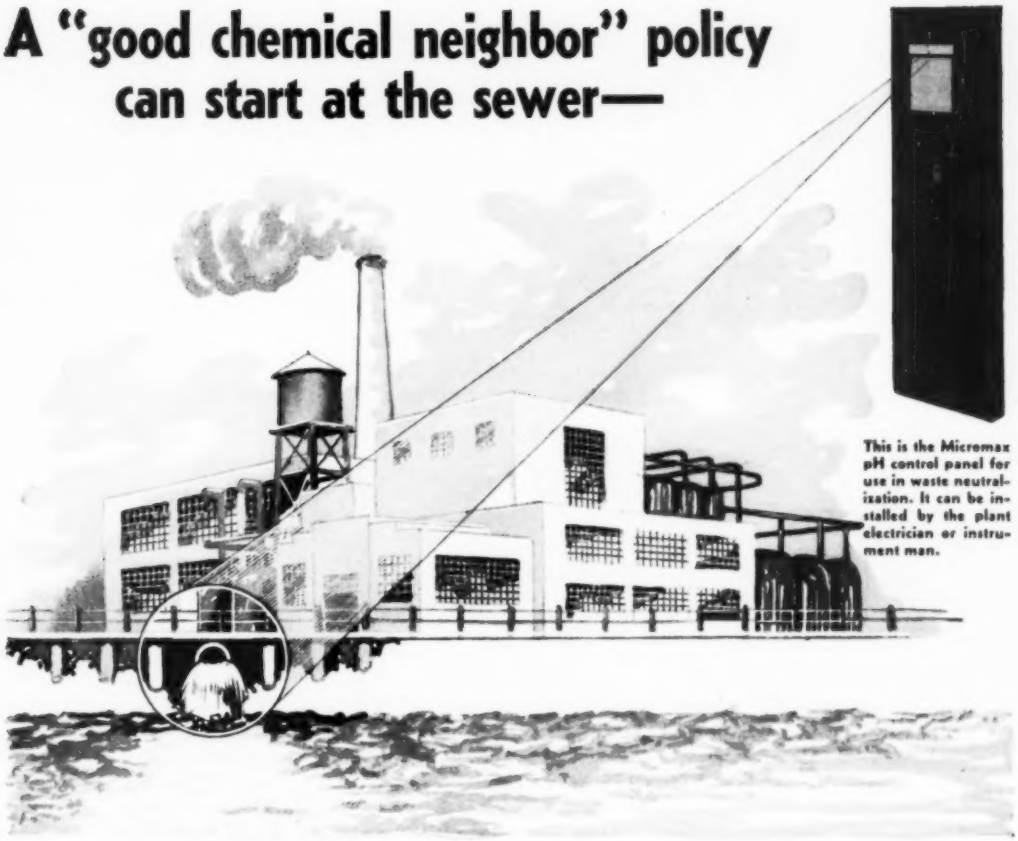
A Bethlehem metallurgist is ready to assist you with the selection of tool steel . . . or to recommend its proper heat-treatment. Plan now to get full details on Bethlehem Tool Steels. There's a Bethlehem sales office or tool-steel distributor near you. Or write us at Bethlehem, Pa.

BETHLEHEM STEEL COMPANY, BETHLEHEM PA.

On the Pacific Coast Bethlehem products are sold by Bethlehem Pacific Coast Steel Corporation
Export Distributor: Bethlehem Steel Export Corporation

BETHLEHEM TOOL STEEL

A "good chemical neighbor" policy can start at the sewer—



This is the Micromax pH control panel for use in waste neutralization. It can be installed by the plant electrician or instrument man.

THE sewer outfall marks the spot where a plant can prevent stream pollution, by discharging only wastes which have been properly treated. And, when proper treatment is linked to pH control, we can probably help . . . effectively. We can assist engineers to set up good "chemical relations" between a company and the rest of the community . . . make the plant a good chemical neighbor.

Our contribution is through Micromax automatic pH control. Correct pH is often the definite assurance that plant wastes are meeting the requirements of good stream chemistry. We can tell you in just a few minutes whether pH on your waste neutralization system — either a present system or a contemplated one — can be controlled automatically; whether you can hold pH within prescribed limits.

Controllability analysis predicts actual results. Through long experience with pH control applications, we have developed a unique system of "controllability analysis". By scientifically weighing all pH control factors — type of waste, treating system, reagent — this analysis determines the net control effect possible for a given waste-treating system.

If you're planning pH control, you can't afford to miss this special service. Our catalog "Effective Neutralization of Industrial Wastes" explains controllability analysis in full detail. For your convenience, it also contains a simple questionnaire . . . so we can help you begin solving your plant's pH problems now. You can answer the questions in just a few minutes.

Ask for Bulletin ND44-96-708. Address Leeds & Northrup Company, 4927 Stenton Ave., Phila. 44, Pa.

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

LEEDS & NORTHRUP CO.

Jrl. Ad ND44-96-708(2)

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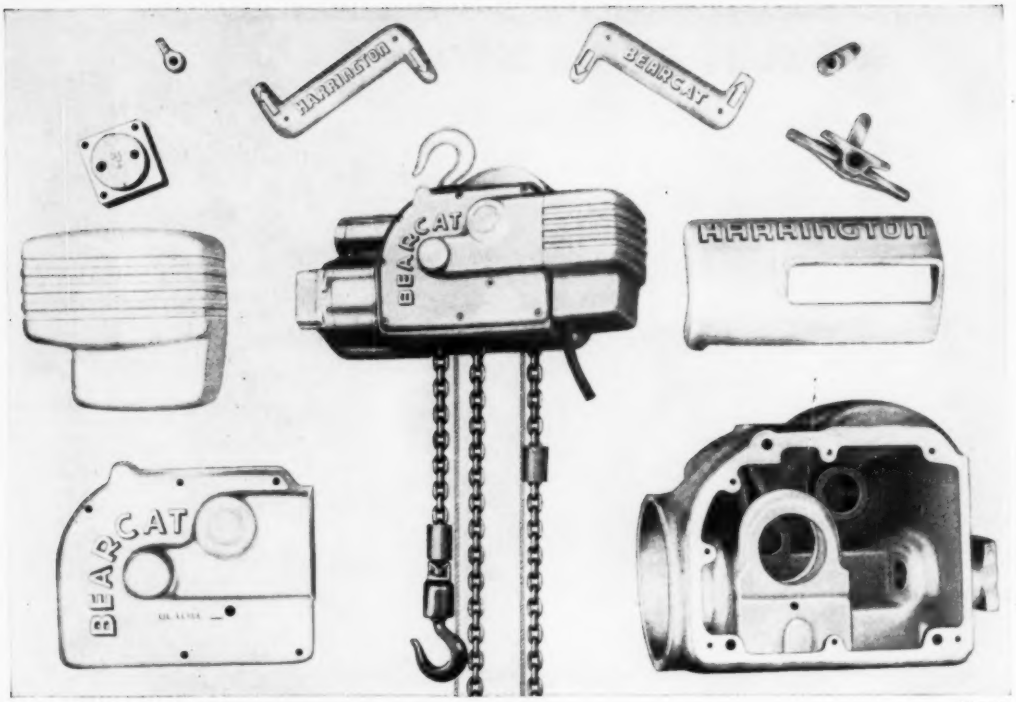
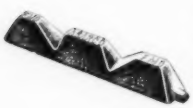


JMLco.F80

Cut Weight, Eliminate Heat Treatment, Improve Properties — with TENZALOY



Casting ten parts of the Bearcat electric hoist (above) in TENZALOY enabled the manufacturer, The Harrington Company, Philadelphia, to:

1. Produce the article without heat treatment, thus saving an added expense.
2. Reduce castings' weight from an average of about 60 lbs. (original ferrous metal design) to 20 lbs., thus improving portability.
3. Cut machining and handling costs.
4. Improve appearance and corrosion properties, thus increasing sales appeal.
5. Virtually eliminate rejects.

The Fisher Casting Company, North Plainfield, N.J., which cast the components shown above, is a longtime user of TENZALOY. Its competent staff knows well this aluminum-magnesium-zinc alloy which Federated developed to give high strength without heat treatment. Therefore, when they recommended TENZALOY, and worked with Harrington and Federated engineers on the project, they were certain of its eventual success.

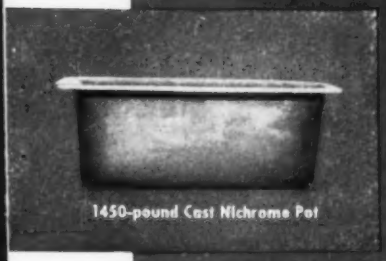
This happy and profitable experience can be yours, too. Write Federated's Dept. CW for technical pamphlet on TENZALOY.

Federated first in the new nonferrous field FMD

Federated METALS DIVISION

AMERICAN SMELTING AND REFINING COMPANY, 120 BROADWAY, NEW YORK 5, N.Y.

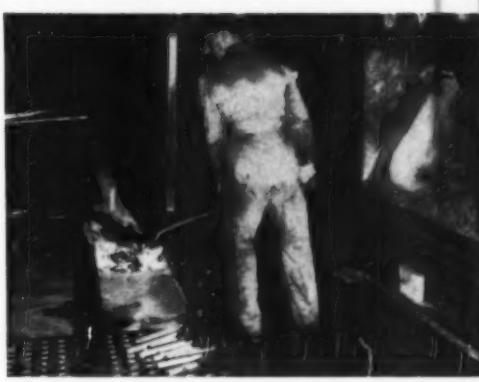
3 YEARS OF heat-treating service at 4½ ¢ per HOUR with NICHROME*



1450-pound Cast Nichrome Pot

Dipping shovels in molten lead during hardening process.

Removing forks from molten lead dip. Note the specially designed Nichrome fixture for fork handling.



Quenching forks after removal from molten lead. (Nichrome fixtures in the foreground.)

. . . that's a fact that went into the record recently at the Union Fork and Hoe Company's Frankfort, N. Y. plant when this cast Nichrome pot was given its "honorable discharge." Used in hardening of shovels and forks, it had given efficient, trouble-free service for *nearly 1100 days.*

Nichrome pots of this type are put into operation filled with molten lead, and are subjected to high temperatures in gas-fired furnaces while serving as heating mediums in the hardening process.

The history of this veteran pot illustrates the exceptional endurance of furnace equipment made of Nichrome—the world famous *high heat-and corrosion-resistant* alloy:

Term of Service

Put into operation.....6 A.M., January 26, 1945
Taken out of service.....8 A.M., January 28, 1948
Total Time: 3 years, 2 days, 2 hours
Under Heat.....1097 days (26,328 hours)
In Production.... 902 days (21,648 hours)—Temperature: 1550°F
Weight of Molten Lead Carried.....4,000 pounds
Pot Cost Per Heat Hour.....$.0447
Pot Cost per dozen forks (shovels) handled: $.0031 per hour

Here is a superb record of efficiency, long life, and low heat-hour costs. . . but one not unusual for Nichrome!

In addition to Nichrome hardening pots, Nichrome fixtures for handling shovels and forks in the molten lead and quench tanks have been adopted as standard equipment by the Union Fork and Hoe Company.

Whatever *your* heat-treating problems, you'll find Nichrome and other D-H cast alloys *unsurpassed* for furnace parts and fixtures. Send us your specifications. We'll be glad to make recommendations based upon your specific requirements.

*Nichrome is manufactured only by

Driver-Harris Company

HARRISON, NEW JERSEY

BRANCHES: Chicago, Detroit, Cleveland, Los Angeles, San Francisco, Seattle

50TH YEAR
SPECIAL PURPOSE ALLOYS SINCE 1899
D H
TRADE MARK REG. U.S. PAT. OFF.
1899 - 1949

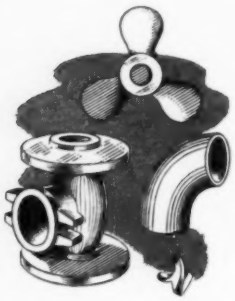
*T.M. Reg.U.S.Pat.Off.

SOLVE YOUR CORROSION PROBLEM

with one of these forms of HASTELLOY alloys
TRADE-MARK

You can obtain HASTELLOY nickel-base alloys in a variety of forms to meet every requirement for high strength and resistance to heat and corrosion. These alloys compare in strength to the high-strength alloy steels, and maintain high strength even at elevated temperatures. HASTELLOY alloys are particularly suitable for equipment that must handle hydrochloric and sulphuric acids . . . free chlorine . . . aqueous solutions containing chlorine or hypochlorites . . . acid solutions of ferric or cuprous salts . . . brine and salt spray.

These alloys can be readily fabricated. Any shop equipped to fabricate the austenitic stainless steels can fabricate them. If you do not do your own fabricating work, we can give you the names of fabricators familiar with handling HASTELLOY alloys. Write for descriptive literature and price lists.

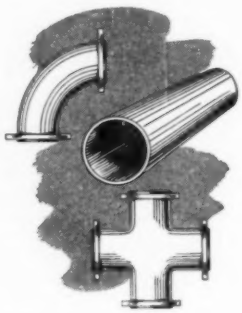


CASTINGS

Simple or intricate sand castings up to 2,000 lb. Precision investment castings in a variety of intricate shapes up to 5 lb.

PIPE AND PIPE FITTINGS

Cast or drawn pipe and welded tubing. Welding, flanged, and threaded fittings in a wide range of standard and special styles and sizes.

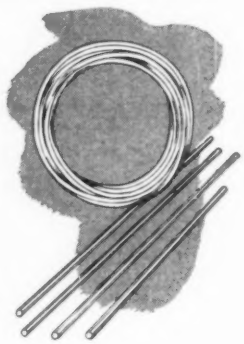


SHEET, PLATE, AND BAR STOCK

Hot-rolled sheet and plate down to 23 B.w.g. (0.025 in.), in widths up to 36 in. Hot-rolled bars from ¼ in. to 3½ in. in diameter.

WELDING ROD, ELECTRODES, AND DRAWN WIRE

Bare rod for oxy-acetylene, HELIARC, or atomic hydrogen welding. Coated electrodes for metallic-arc welding. Wire coils for UNIONMELT welding, metal-spraying, and fabricated wire products.



HAYNES alloys
TRADE-MARK

Haynes Stellite Company
Unit of Union Carbide and Carbon Corporation
UCC
General Offices and Works, Kokomo, Indiana
Sales Offices
Chicago—Cleveland—Detroit—Houston
Los Angeles—New York—San Francisco—Tulsa

The terms "Haynes," "Hastelloy," "Heliarc," and "Unionmelt" are trade-marks of Units of Union Carbide and Carbon Corporation.

New!

Rolock, Inc., announces a new, important development . . . one-piece Inconel* sand seal rings.

This new one-piece construction permits accurate reproduction of both cross-sectional shape and diameter, insures good fit between seal and retort body, is readily installed, and offers the additional advantages of Inconel construction.

Like other leading fabricators of heat-treating equipment, Rolock, Inc. recommend Inconel for such high heat applications. Fixtures made of Inconel have, time and again, outlasted those of other metals in many of industry's hottest assignments.

Inconel is resistant to high temperature corrosion—is able to withstand temperatures as high as 2100° F. It resists cracking and scaling, even in inherently corrosive furnace atmospheres. Welds in Inconel are as resistant to corrosion, embrittlement, and oxidation as the alloy itself.

If you want to cut losses from corrosion and heat damage . . . and save on fuel costs . . . replace with lighter-weight wrought Inconel fixtures. Inco's Technical Service Department will gladly study your metal problems and make impartial recommendations . . . without charge, of course.

*Reg. U. S. Pat. Off.

For full information about Rolock one-piece Inconel sand seal rings, write to:
ROLOCK, INC., 1240 Kings Highway, Fairfield, Conn.

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street, New York 5, N. Y.

Inconel retort with one-piece Inconel sand seal ring. The elimination of radial welds on the seal ring minimizes distortion and promotes better fit between ring and retort body. Rolock one-piece sand seals are available in three sizes: 22", 27", and 33" in diameter.

EMBLEM OF SERVICE
INCO
TRADE MARK

INCONEL*...for long life at high temperatures

no more hand-me-downs

for stainless sheet and strip

Stainless sheet and strip production is coming of age—no longer made on the hand-me-downs of carbon steel production, thanks to modern advances in strip mill practice. CRUCIBLE, drawing on this progress and on generations of *specialty* experience, has carried stainless development even further by building the world's first complete mill designed *specifically* for hot and cold rolling of stainless steels. In this $18,000,000 project, every building, every piece of equipment, has been built to incorporate the *best* of accepted modern practice, PLUS exclusive features designed by CRUCIBLE's industry-famous technical staff.

Here stainless sheet and strip is produced in widths from ½″ to 50″ inclusive, in all gauges, grades and finishes. This new and important contribution to the production of stainless steel is vital news to every processor of stainless steel products. For now CRUCIBLE, one of the pioneers in stainless steels, rounds out an integrated program of stainless in all its forms—sheets, strip, plates, bars, wire, forgings, castings and tubing (manufactured by the new subsidiary, Trent Tube Co.). To this program CRUCIBLE has applied its *specialty product* methods of quality control, methods that have given CRUCIBLE leadership in special purpose steels for half a century. Data sheets for all grades are yours for the asking. Your inquiries will be welcomed.

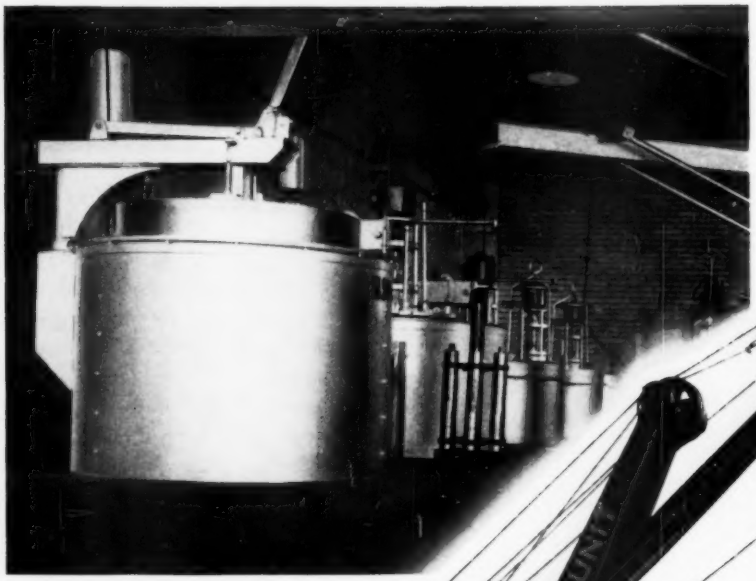
new tools for a **MASTER** mechanic

CRUCIBLE STEEL COMPANY OF AMERICA
405 Lexington Ave,. New York 17, N. Y.
Branches, Warehouses and Distributors in Principal Cities

CRUCIBLE first name in special purpose steels

hot and cold rolled **STAINLESS SHEET AND STRIP**

STAINLESS • HIGH SPEED • TOOL • ALLOY • MACHINERY • SPECIAL PURPOSE • STEELS



Case History at UNIT CRANE: In addition to Carburizing, Normalizing and Tempering operations, Hevi Duty furnaces are used to harden Drive Tumbler Shafts of NE 8642 steel to give them an unusual degree of strength.

¾ Yard Unit Shovel; a nimble, fast-moving shovel that moves material quickly and dependably at low cost. It's light enough for fast-moving action yet has dependable power and reliable performance.

HEVI DUTY FURNACES

help Unit Crane & Shovel Corp. build quality products . . . . .

Earth-moving and other types of material handling equipment made by Unit Crane and Shovel Corporation have achieved a reputation for good design, . . . a design that results in speed, responsiveness and brawn. Equally important is their modern method of heat treating critical parts in Hevi Duty furnaces. Anton Tylock, heat treating foreman says, "I've worked with Hevi Duty furnaces for 20 years . . . they're dependable, easy to keep at heat . . . and accurate".

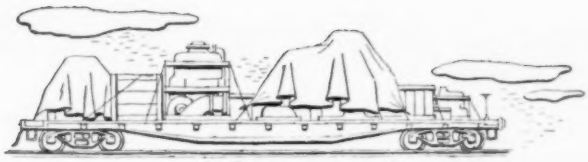
Many of the outstanding advantages of Hevi Duty furnaces plus construction details and methods of procedure are to be found in Bulletins HD 1245 and HD 646. Write for your copies today.

HEVI DUTY ELECTRIC COMPANY

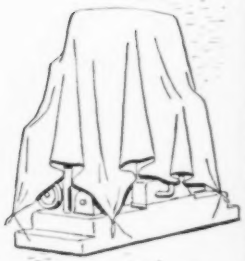
HEAT TREATING FURNACES **HEVI DUTY** ELECTRIC EXCLUSIVELY

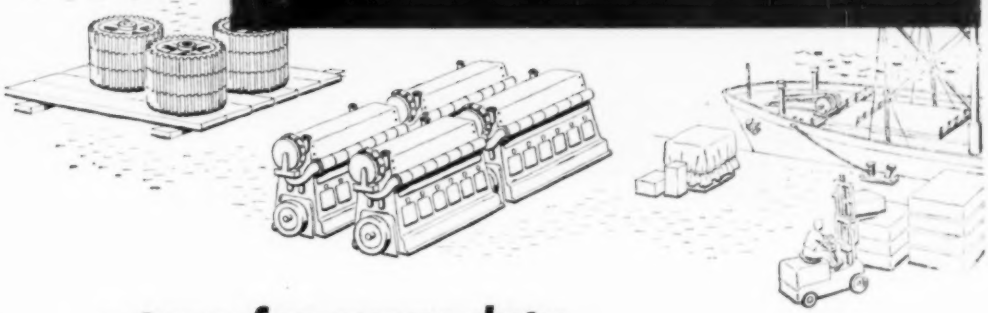
DRY TYPE TRANSFORMERS — CONSTANT CURRENT REGULATORS

MILWAUKEE 1, WISCONSIN



Gulf offers a complete line of *Quality Rust Preventives*





. . . a type for every duty, protection against all exposures

FROM the complete Gulf line of quality rust preventives, you can select the proper coatings to fit the desired methods of application, types of metal, length of time for which protection is required, conditions of storage or shipment, and ease of removal.

Gulf makes available both oil- and petrolatum-type rust preventives for both interior and exterior use—including the well known Gulf No-Rust C (polar type) which displaces residual moisture on metal surfaces and lays down a protective coating; and Gulf No-Rust Engine Oils, which prevent corrosion caused by products of combustion left in internal combustion engines.

A Gulf Lubrication Engineer will be glad to co-operate with you in the solution of your corrosion problems. Write, wire, or phone your nearest Gulf office today.

Gulf Oil Corporation · Gulf Refining Company

Division Sales Offices:

Boston · New York · Philadelphia · Pittsburgh · Atlanta
New Orleans · Houston · Louisville · Toledo

GULF INDUSTRIAL LUBRICATION

Gulf Oil Corporation · Gulf Refining Company MP
3800 Gulf Building, Pittsburgh 30, Pa.

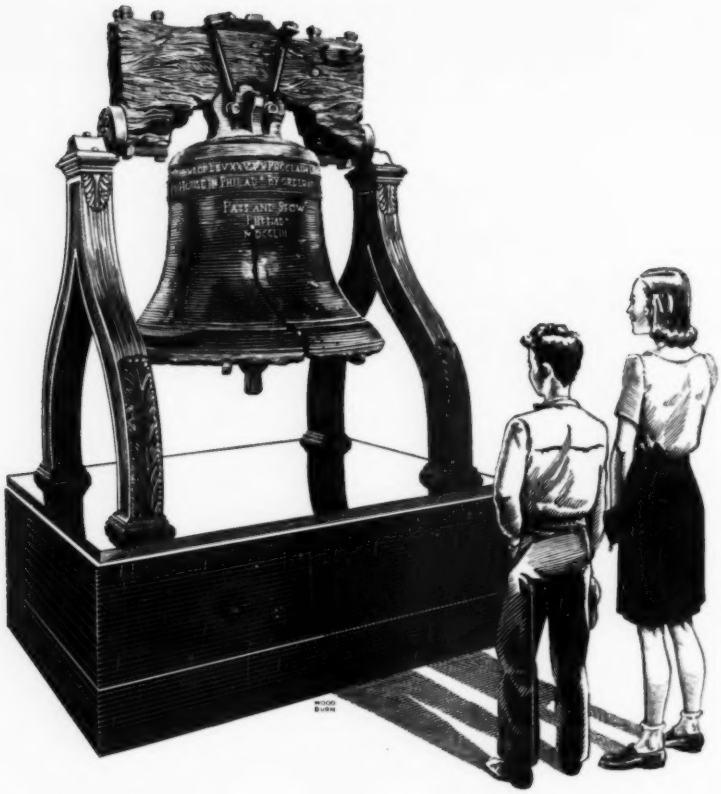
Please send me, without obligation, a copy of your pamphlet "Gulf Rust Preventives."

Name.....

Company.....

Title.....

Address.....



What price liberty?

IT was Daniel Webster who said, "God grants liberty only to those who love it and are always ready to guard and defend it."

Today in our yearning for "security", we are inclined to forget about that "liberty" for which this old bell rang out. The two are not synonymous. When we permit a benevolent government to assume more and more responsibility for housing, feeding, hospitalizing, and even entertaining our citizens, we must in return expect to surrender more and more of our personal rights and liberties.

Actually, the only security any man can enjoy with liberty is the security he earns through his own initiative, resourcefulness and productivity. As community leaders, it is our responsibility to help our fellow citizens realize that for the delusion of government-guaranteed security they are sacrificing liberty.

The Youngstown Sheet and Tube Company

General Offices--Youngstown 1, Ohio
Export Offices--500 Fifth Avenue, New York

MANUFACTURERS OF CARBON, ALLOY AND YOLOY STEELS

ELECTROLYTIC TIN PLATE - COKE TIN PLATE - WIRE - COLD FINISHED CARBON AND ALLOY BARS - PIPE AND TUBULAR PRODUCTS - CONDUIT - RODS - SHEETS - PLATES - BARS - RAILROAD TRACK SPIKES.

the trend is to N-A-X HIGH-TENSILE STEEL for

BUMPERS • GRILLES • HOODS
FENDERS • BODY PANELS • DECK LIDS
FRAMES • BRACINGS • WHEELS • HUB CAPS
AND OTHER AUTOMOTIVE PARTS

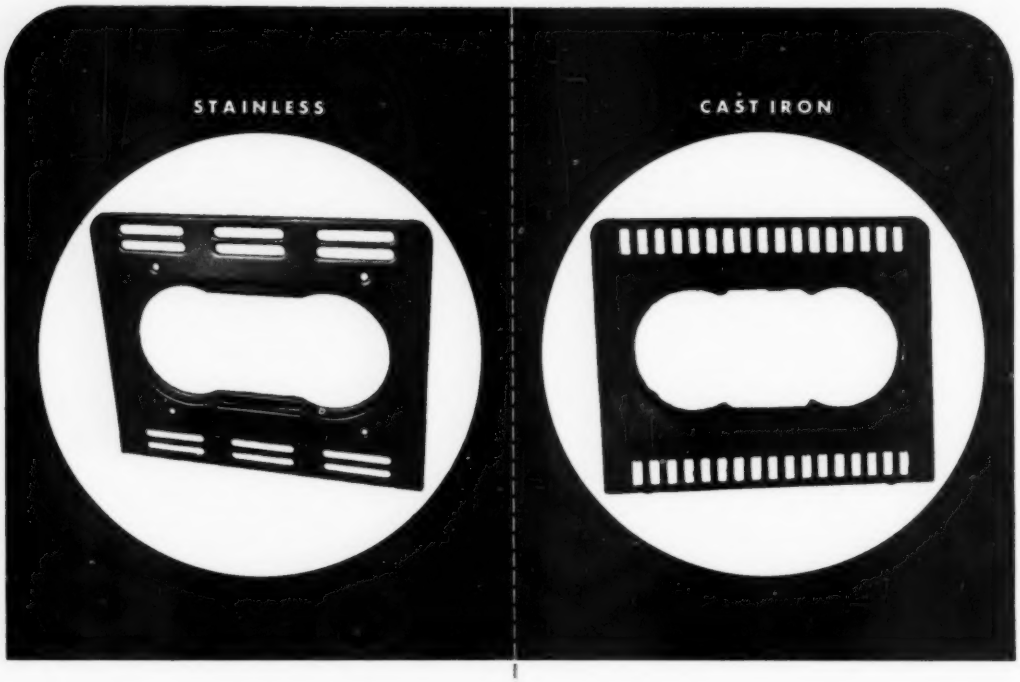
for High Strength • Finer Grain Structure • Good Formability • Great Impact-Toughness • Excellent Weldability
High Corrosion-Resistance • High Fatigue-Resistance

N-A-X HIGH-TENSILE MEETS ALL REQUIREMENTS OF S.A.E. 950

Specify N-A-X HIGH-TENSILE STEEL

GREAT LAKES STEEL CORPORATION

N-A-X ALLOY DIVISION • DETROIT 18, MICHIGAN
Unit of National Steel Corporation



Where Stainless Costs Less Than Cast Iron!

COST-CASE OF A STOVE TOP
(From Actual Records)

3/16" IRON CASTING		.050" ARMCO 17 STAINLESS STEEL	
Weight of Casting	10 lbs.	Weight of Blank	4.1 lbs.
Cost of Casting	$ .90	Cost of Blank	$ 1.39
Pre-Enamel Finish	.20	Stamping	.04
Enameling Cost	.60	Blackening	.15
	$ 1.70		$ 1.58
5% Rejections	.08	1% Rejections	.02
	$ 1.78		$ 1.60

This case of a stainless steel stove top that costs *18 cents less* than a cast iron top is another example of the savings that more and more manufacturers are making with Armco Stainless Steels.

And besides the savings shown in this cost breakdown, the manufacturer salvages the stamped-out stainless center section for another important part of the range. Shipping costs on the stove are lower too, because the finished stainless top weighs 7 pounds less than the iron casting.

So the manufacturer cashes in on a substantial cut in production costs, and the housewife gets a better kitchen range. The stainless top is more corrosion resistant, lighter, and won't break.

This is one example where the handsome appearance of Armco Stainless has nothing to do with its selection for the stove top. The part is blackened by the Armco Blackening Process to maintain color uniformity at high temperatures.

Using Armco Stainless Steels to *cut first-cost* and improve products or equipment is nothing new; it may be possible in your business too. So why not take the first important step today by analyzing *your* finished product costs using this rustless steel. Armco engineers will be glad to talk it over with you.

Just address Armco Steel Corporation, 3579 Curtis Street, Middletown, Ohio.

ARMCO STEEL CORPORATION

Steelmakers are called upon to meet increasingly exacting requirements for cleanliness, quality, and chemical composition of steel. To help steelmakers produce these better steels, ELECTROMET has worked constantly to produce better ferro-alloys. Here are some of the reasons . . .

. . why

"ELECTROMET" Alloys

Trade-Mark

are preferred

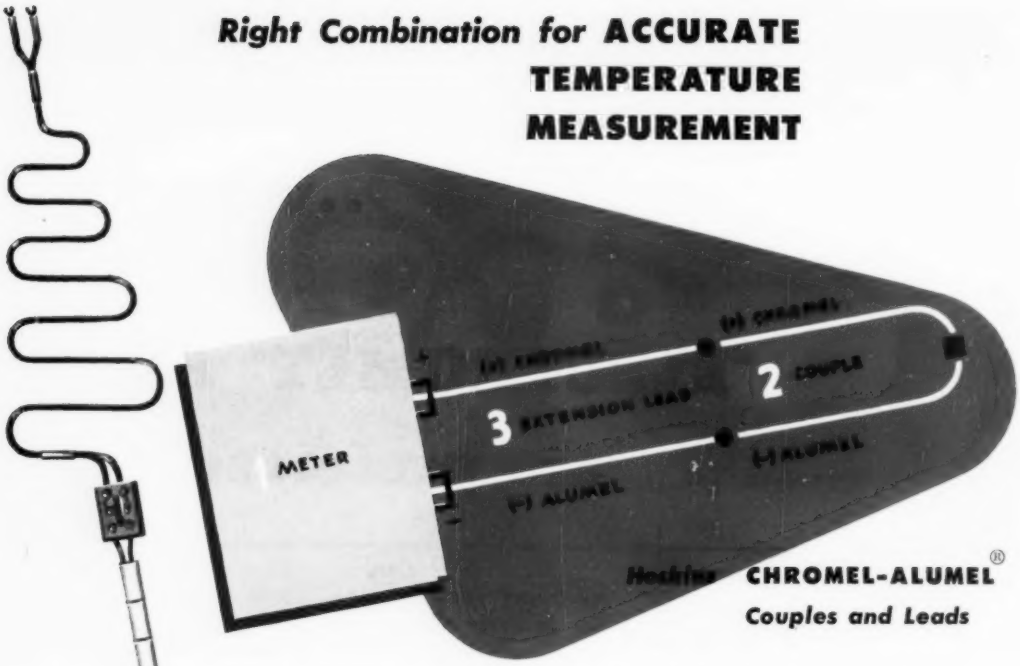
1 UNIFORMITY OF ANALYSIS	ELECTROMET's specifications and dependable chemical analysis permit the use of the average analysis in calculating charges. In every shipment of ELECTROMET ferro-alloys, you obtain a uniform product resulting from close metallurgical and physical control.
2 WIDE RANGE OF SIZES	An adequate range of sizes, for both lump and crushed material, allows you to select the size best suited to your scale of operations and type of melting facilities for open hearth, electric furnace, or foundry.
3 GOOD SERVICE	ELECTROMET alloys are available for immediate shipment from plants and warehouses that are conveniently located to serve you. Sufficient stocks are kept on hand to meet the varied requirements of ferro-alloy users. Our staff of experienced metallurgical engineers is always ready to give technical help where needed.

The word "Electromet" is a registered trade-mark of Union Carbide and Carbon Corporation

Write for our new catalog "Electromet Ferro-Alloys and Metals." It describes over 50 metals and alloys produced by ELECTROMET and tells of the unique technical service offered to the metal industries.

ELECTRO METALLURGICAL DIVISION
Union Carbide and Carbon Corporation
30 East 42nd Street UCC New York 17, N. Y.
OFFICES: Birmingham • Chicago • Cleveland • Detroit
New York • Pittsburgh • San Francisco
In Canada: Electro Metallurgical Company of Canada, Limited, Welland, Ontario
Warehouses: Chicago • Los Angeles • Oakland, Calif. • Portland • Sheffield, Ala.

Right Combination for ACCURATE TEMPERATURE MEASUREMENT



Hoskins **CHROMEL-ALUMEL**®
Couples and Leads

If you're concerned with accurate temperature measurement in your heat treating operations, you'll do well to check your meter installations against the diagram shown above. It means simply this:

(1) Make sure your pyrometers are of recent manufacture . . . precision built . . . capable of accurately registering true temperature—EMF values . . . and calibrated for dependably accurate Chromel-Alumel Thermocouples.

(2) Standardize on durable Chromel-Alumel Thermocouples. They're highly responsive to temperature fluctuations . . . so resistant to oxidation you need not pack the protection tube. And they carry a positive accuracy guarantee of ± 5°F. from 32° to 660°F., and ± ¾% at temperatures above 660°F.

(3) Then, of course, complete your chain of accuracy by using Chromel-Alumel "extension" leads. For, by using wires of identical compositions for both couples and leads, you eliminate all possibility of "cold-end" errors.

Our Catalog M¹ tells the complete technical story . . . and additional reference can be found in the following Bureau of Standards Research papers: R.P. 767—"Standard Tables for Chromel-Alumel Thermocouples"; R.P. 768—"Methods of Testing Thermocouples"; R.P. 1278—"Stability of Base Metal Thermocouples in Air at 800° to 2200°F."

Chromel-Alumel couples and leads are available through your pyrometer manufacturer.

HOSKINS MANUFACTURING COMPANY
4445 LAWTON AVE. • DETROIT 8, MICHIGAN

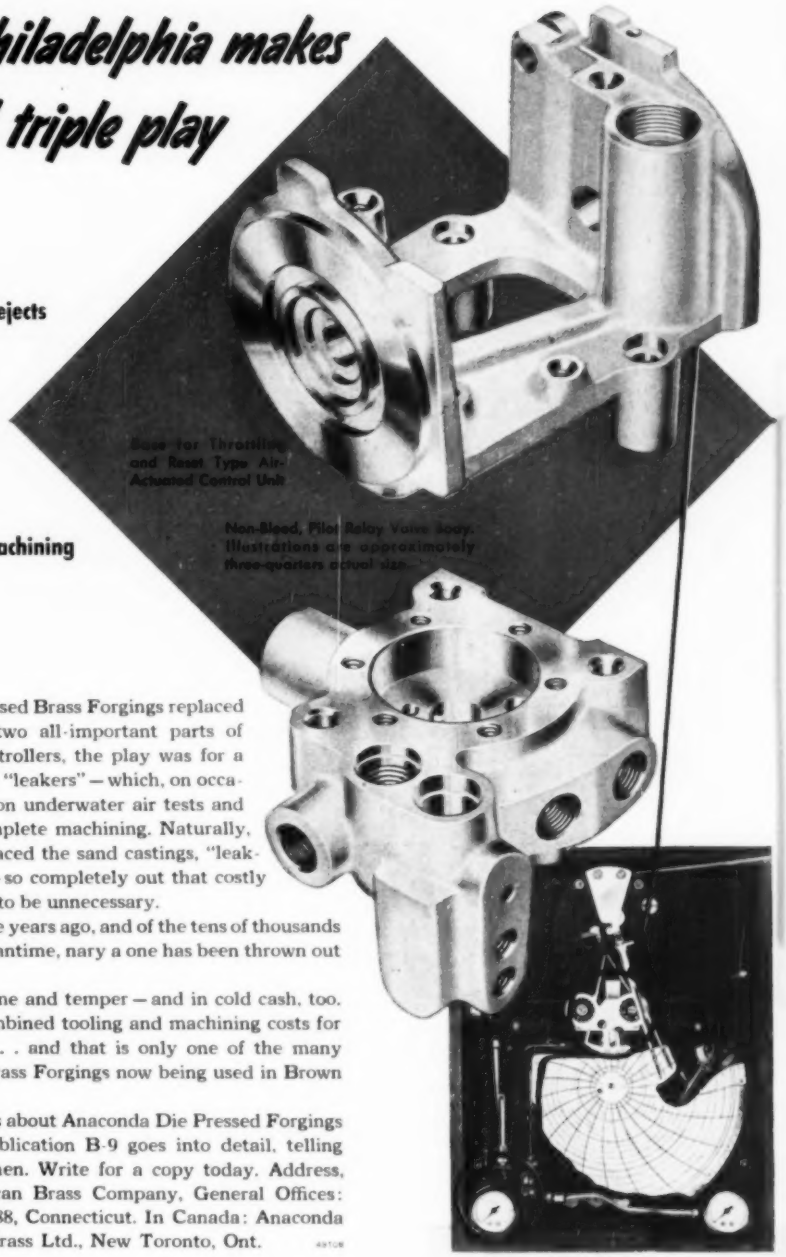
Heating Element Alloys ★ Heat Resistant Alloys ★ Thermocouple Alloys ★ Spark Plug Electrode Wire ★ Special Alloys of Nickel ★ Electric Heat Treating and Laboratory Furnaces

Brown of Philadelphia makes unexpected triple play

1 Abolishes costly rejects

2 Eliminates unit air testing

3 Saves 16% on machining


Base for Throttling and Reset Type Air-Actuated Control Unit
Non-Bleed, Pilot Relay Valve Body.
Illustrations are approximately three-quarters actual size.

When Anaconda Die Pressed Brass Forgings replaced sand castings for these two all-important parts of Brown Air Operated Controllers, the play was for a single out — elimination of "leakers" — which, on occasion, ran as high as 60% on underwater air tests and showed up only after complete machining. Naturally, when *wrought* metal replaced the sand castings, "leakers" were out by a mile — so completely out that costly unit air testing was found to be unnecessary.

That was more than nine years ago, and of the tens of thousands of forgings used in the meantime, nary a one has been thrown out for porosity.

Savings? Plenty — in time and temper — and in cold cash, too. For instance: 16% on combined tooling and machining costs for the base forging alone . . . and that is only one of the many Anaconda Die Pressed Brass Forgings now being used in Brown Instruments.

There are a lot of things about Anaconda Die Pressed Forgings you'll want to know. Publication B-9 goes into detail, telling where, why, how and when. Write for a copy today. Address, The American Brass Company, General Offices: Waterbury 88, Connecticut. In Canada: Anaconda American Brass Ltd., New Toronto, Ont.

ANACONDA

Anaconda
DIE PRESSED FORGINGS

BROWN

This is the Brown AIR-O-LINE Recording Flow Controller, manufactured by the Minneapolis-Honeywell Regulator Co., Brown Instruments Division, Philadelphia. Brown Air Operated Instruments are used the world over for automatically controlling temperature, pressure, flow, liquid level and humidity in industrial processes.

Don't just pick any wire

Let us make it to fit the job exactly

Here in the mills of The American Brass Company, more than 100 different copper alloys are processed into wire in an almost unlimited variety of sizes and shapes, tempers and finishes. The result is that each wire is, in effect, tailor-made . . . especially adapted to particular problems of tooling, rate of production, and desired properties of the finished product. And there's a big difference – both in quality and unit cost – when the wire is exactly suited to the job!

. The column at the right very likely holds the combination to that "one best wire". Our Technical Department will help you find it – and it may be easier than you think. Your inquiry entails no obligation whatever.

THE AMERICAN BRASS COMPANY

General Offices: Waterbury 88, Connecticut
Subsidiary of Anaconda Copper Mining Company
In Canada: Anaconda American Brass Ltd., New Toronto, Ont.

ANACONDA
from mine to consumer

Anaconda
COPPER and COPPER ALLOY
Wire

TYPICAL TYPES OF WIRE

Pin Wire	Hook & Eye Wire	Nail Wire
Screw Wire	Cotter Pin Wire	Rivet Wire
Chain Wire	Brake Lining Wire	Tie Wire
Slide Fastener Wire	Fourdrinier Wire	Welding Wire
Jewelry Wire	Trolley Wire	Brazing Wire

MATERIALS

Copper	Brass	*Hitenso Cadmium Bronze
Chromium Copper	Zinc	*Calsun Bronze
Deoxidized Copper	Phosphor Bronze	Ambraloy
Silver Bearing Copper	Nickel Silver	Special Copper Alloys
Gilding	Cupro Nickel	*T.M. Reg. U.S. Pat. Off.
Commercial Bronze	*Everdur	

SIZES AND SHAPES .002" TO .750"

(Extreme limitations—varying according to alloy and shape)

Round	Half-oval	Square
Half-round	Flat	Hexagonal
Oval	Keystone	Octagonal
	Irregular Shapes on Order	

FINISHES AND TEMPERS

Cadmium Plated	Bare	Oxidized
Bright Annealed	Tinned	

From Soft Annealed through Spring Tempers; put up on Spools, Reels, Coils or cut to Straight Lengths.

SUITABLE FOR THESE FABRICATING OPERATIONS

Redrawing	Riveting	Braiding
Cold Heading	Machining	Spinning
Hot Heading	Flat rolling	Weaving
Extruding	Edgewise winding	

ROLOCK

FABRICATED ALLOYS

Inconel Homocarb Furnace Retorts with *One Piece* Fabricated Sand Seal Rings

Rolock's construction of sand seals adds the exclusive and crowning feature that makes this Inconel Homocarb furnace retort a leader in its field. All radial welds are eliminated . . . Inconel seal is integral with retort.

The One Piece seal, truly round, insures perfect fit; wrought material with sound, full penetration, gas tight welds . . . the weld metal having the same strength and resistance to high heat and corrosion as the parent metal itself . . . prevents atmosphere leakage, lengthens life of electric heating elements, reduces maintenance.

If you've been troubled by embrittlement from carburizing or gas cyaniding atmospheres, and you want to cut heating costs, improve work, specify Rolock Inconel Retorts with the tried and proven One Piece integral Sand Seal.

Fabricated Inconel Retort . . . available for 15", 20" and 25" Homocarb furnaces.

It's one piece . . . It's Inconel . . . It's Integral with the retort . . . It's exclusively a ROLOCK design for original or replacement equipment.

Offices in: PHILADELPHIA • CLEVELAND • DETROIT • INDIANAPOLIS • CHICAGO • ST. LOUIS • LOS ANGELES • HOUSTON

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JOB-ENGINEERED for better work Easier Operation, Lower Cost

VISIT US AT BOOTH 829 Metal Show, Cleveland, Oct. 17

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Centrifugal roll—cast from Thermalloy "30".
Radiant Tube Assembly —Centrifugally cast from Thermalloy "40".
Centrifugal Retort Tubes and Locking Plugs. Thermalloy "40-B".
Roll for roller bottom furnace—Centrifugally cast body of Thermalloy "40".

Let's talk *FACTS* about CENTRIFUGAL CASTINGS

We make both centrifugal castings and static castings. We don't make a blanket claim that centrifugal castings are denser, more uniform or stronger. In certain cases, this has proved to be true. But for all practical purposes, the differences in physical properties are almost negligible.

Thinner wall sections can be produced more economically by centrifugal casting than by static casting.

The amount and location of machining must be considered. Centrifugal casting produces a smoother outside surface than static casting. However, shrinkage areas are usually found on the inside surface, making it necessary to provide more machining stock if a finished surface is required.

In some cases, costs may be lower for centrifugal castings than for static castings—but this depends entirely upon the individual casting to be produced.

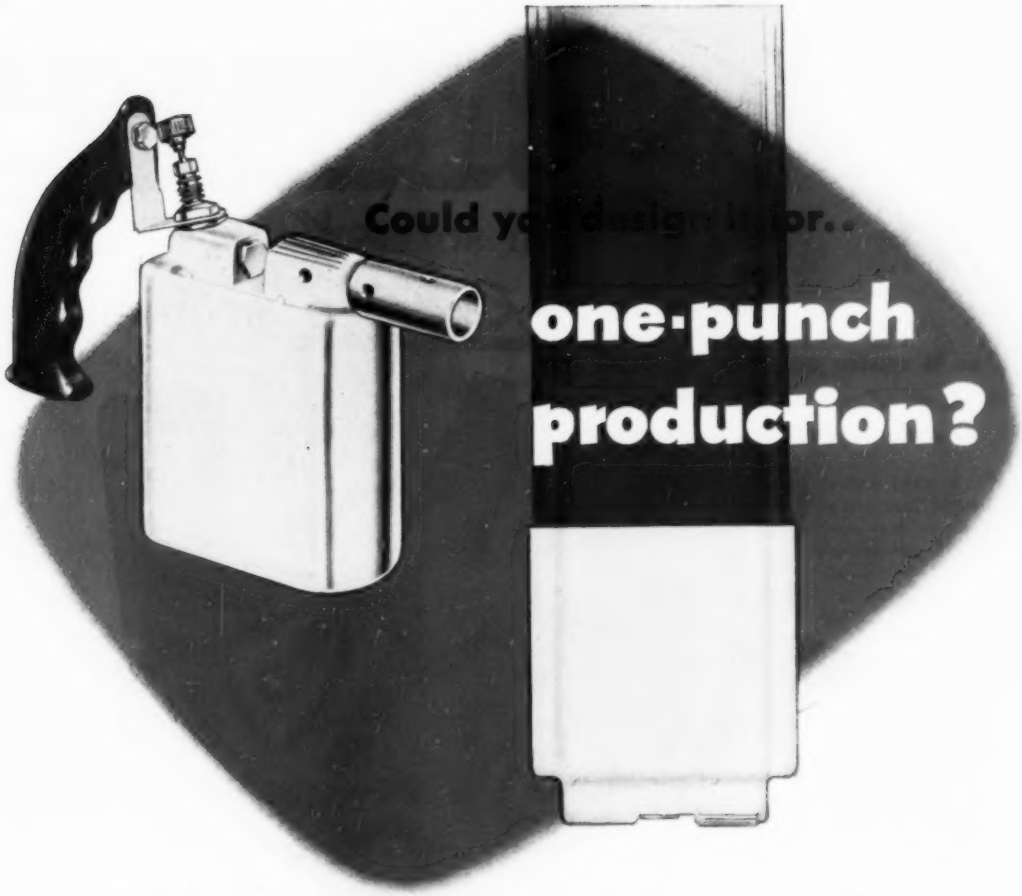
We recommend that you let our experienced metallurgists work with you in selecting the most economical type of casting for your application. You may be sure of a practical and unbiased recommendation. Call your nearest Electro-Alloys engineer, or write Electro-Alloys Division, 1976 Taylor Street, Elyria.

Specify CHEMALLOY* for corrosion resistance
THERMALLOY* for heat and abrasion resistance

*Reg. U. S. Pat. Off.

AMERICAN Brake Shoe COMPANY

ELECTRO-ALLOYS DIVISION
ELYRIA, OHIO



Alcoa's Impact Extrusion process formed this blowtorch housing—charging well, torch tube housing, handle and valve mounting—with just one punch!

Impact extrusions can often give you any symmetrical shape at substantially lower cost than spinning, stamping, drawing or machining; widest choice of finishes, too—from as-delivered to patented Alumilite. You get all these in addition to Alcoa Aluminum's light weight, strength, corrosion resistance, handsome appearance.

Get the whole story about how this versatile process can give your product more sales appeal at lower cost! Call your nearby Alcoa sales office. Or write for your free copy of "Alcoa Aluminum Impact Extrusions" to ALUMINUM COMPANY OF AMERICA, 2101J Gulf Bldg., Pittsburgh 19, Pa.

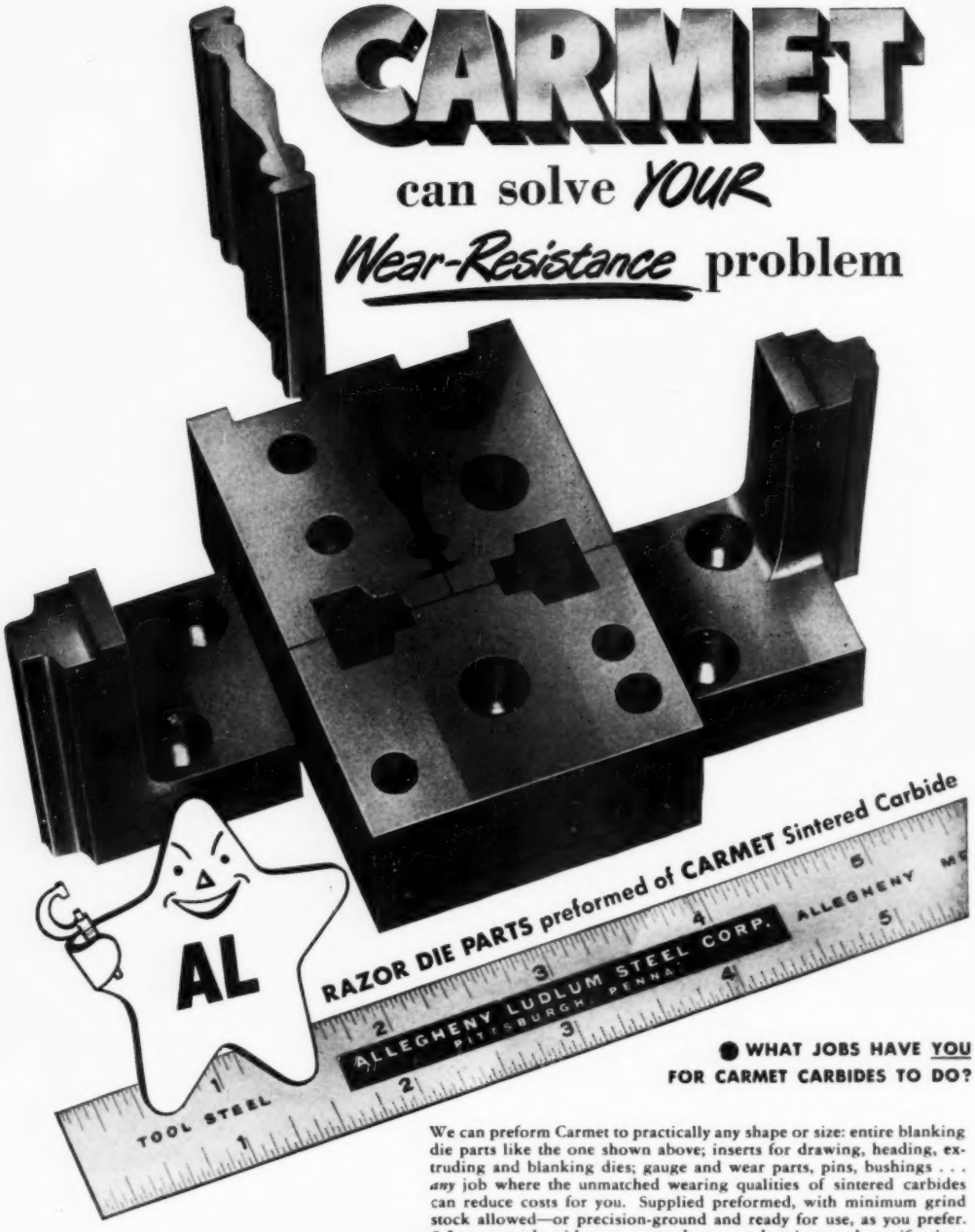
ALCOA *Aluminum* **IMPACT EXTRUSIONS**

ALCOA ALUMINUM

INGOT • SHEET & PLATE • SHAPES, ROLLED & EXTRUDED • WIRE • ROD • BAR • TUBING • PIPE • SAND, DIE & PERMANENT MOLD CASTINGS • FORGINGS • IMPACT EXTRUSIONS
ELECTRICAL CONDUCTORS • SCREW MACHINE PRODUCTS • FABRICATED PRODUCTS • FASTENERS • FOIL • ALUMINUM PIGMENTS • MAGNESIUM PRODUCTS

CARMET

can solve *YOUR* *Wear-Resistance* problem



● WHAT JOBS HAVE YOU FOR CARMET CARBIDES TO DO?

We can preform Carmet to practically any shape or size: entire blanking die parts like the one shown above; inserts for drawing, heading, extruding and blanking dies; gauge and wear parts, pins, bushings . . . *any* job where the unmatched wearing qualities of sintered carbides can reduce costs for you. Supplied preformed, with minimum grind stock allowed—or precision-ground and ready for use, as you prefer. ● Let us work with you . . . send us your drawings and specifications for quotations.

Allegheny Ludlum Steel Corporation

CARBIDE ALLOYS DIVISION, Detroit 20, Michigan

Distributors: Write us about handling CARMET Standard Tools in your area.

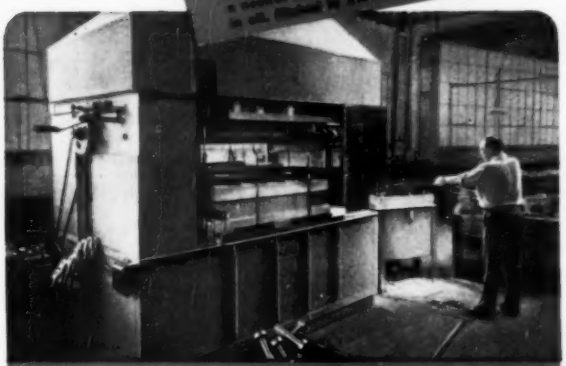
WAD 2413

NEUTRAL HARDENING

means just what it says . . .

No Scale No Decarb

Photomicrograph showing absence of scale or decarburization in a section of S.A.E. 1085 Steel (X100) hardened at 1550° F. in a neutral salt bath and quenched in oil. Etched in 3% nital.



Automotive spline shafts being heated in a neutral salt bath equipped with a screw-conveyor mechanism. Temperature of the work is held within 5°F. even in this relatively large bath — 6 ft. long, 2 ft. wide and 2 ft. deep.

For more information on AJAX Electric Salt Bath Furnaces and their many uses — hardening, annealing, brazing, tempering, cleaning, quenching, etc. — metalurgists and metalworking executives are invited to write on their firm's letterhead for the new 72-page Booklet No. 116.

AJAX ELECTRIC COMPANY, INC.

910 Frankford Avenue • Philadelphia 23, Pa.

The World's Largest Manufacturer of Electric Heat Treating Furnaces Exclusively!

Associate Companies: **Ajax Metal Co.** **Ajax Engineering Corp.** **Ajax Electric Furnace Corp.** **Ajax Electrothermic Corp.**
In Canada: Canadian General Electric Co., Ltd., Toronto, Ont.

. . . and an amazing volume of work can be treated in small, relatively inexpensive salt bath equipment.

A neutral salt bath provides an ideal means of heating carbon or alloy steel parts without any deleterious effect on the surface, such as scaling, pitting, carburizing or decarburizing. The bath completely seals out all air while work is heating . . . and a thin film of salt remains when work is removed, protecting it right up to the instant of quenching.

All "protective atmospheres," gas generating equipment and specially trained operators required for their use are eliminated . . . with corresponding savings in initial expense, operating costs and floor space requirements.

Heating cycles are 4 to 6 times faster than in atmosphere or radiant type furnaces — enabling small furnaces to handle a large volume of work — because heat is transferred by conduction rather than by convection or radiation, all surfaces of the work being in direct physical contact with the molten salt. Heating, therefore, is both rapid and uniform . . . eliminating the cause of most distortion.

Unique internal heating principle of the AJAX furnace — utilizing patented, closely-spaced, immersed electrodes — produces an automatic electrodynamic stirring action within the bath which contributes to faster heating of the work and assures a temperature variation of less than 5° F. throughout the bath.

This internal heating feature also permits use of long-lived ceramic pots, avoiding contamination of neutral baths by metallic oxides produced by metal pots.

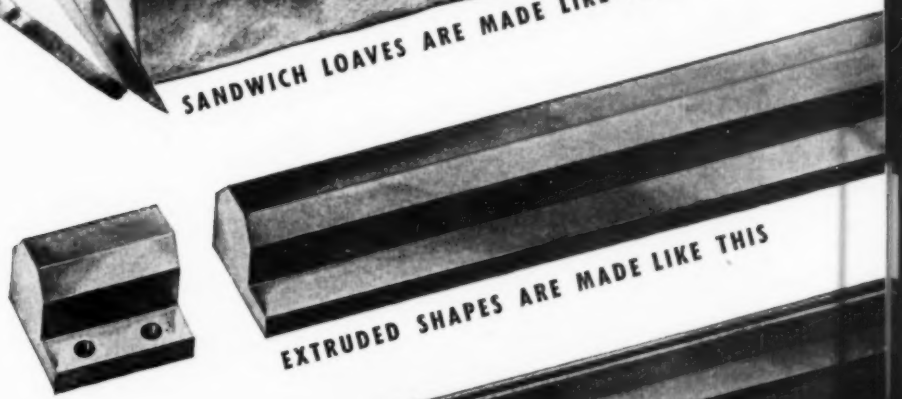
The advantages of hardening in a neutral salt bath can be further enhanced by use of an isothermal salt bath quench (martempering or austempering) to hold distortion to a minimum and eliminate quench cracking.

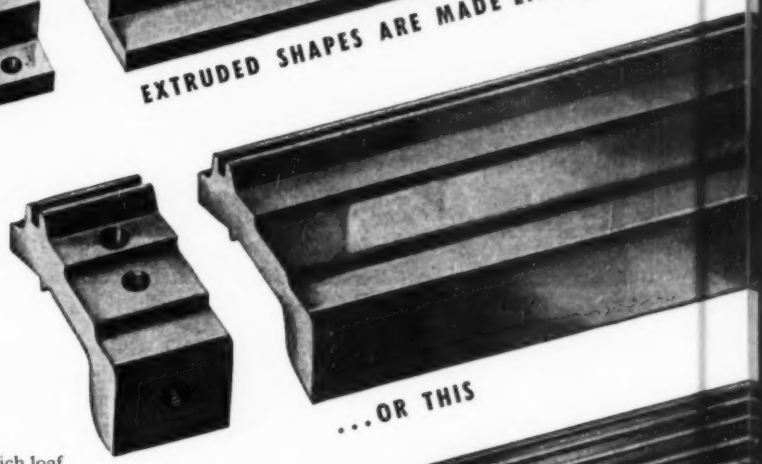
SEE US AT THE METAL SHOW — BOOTH 1901.

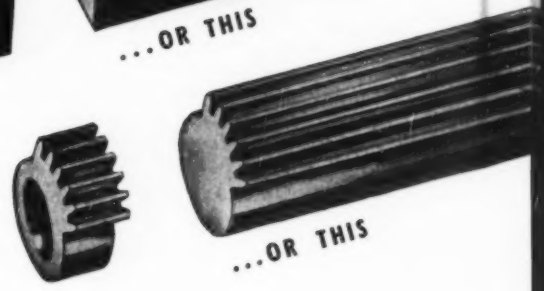
SELF-HEATING • SELF-CIRCULATING

AJAX HULTGREN **ELECTRIC SALT BATH FURNACES**

TORQUE
Wallace Barnes Springs
Bristol Connecticut







THE OBJECT
to SAVE TIME— REDUCE WASTE

There's very little waste on a sandwich loaf. That's because it was especially designed for its particular job.

And that's the way it is with Anaconda Extruded Shapes. Almost-finished blanks are literally "sliced" off long, mill-length bars that are made as close as possible to the cross-section of the finished product. Doing it this way, you just can't help saving metal, money and machining.

You're likely to find (as hundreds of other manufacturers have) that quality goes up while costs come down when you switch to Extruded Shapes, because extruded metal is *wrought* metal . . . readily machinable, strong, tough, dense-grained and smooth-surfaced. We'll be glad to make suggestions on receipt of a sketch or sample.

THE AMERICAN BRASS COMPANY

General Offices: Waterbury 88, Connecticut 49107

Subsidiary of Anaconda Copper Mining Company

In Canada: Anaconda American Brass Ltd., New Toronto, Ontario

ANACONDA from mine to consumer

Anaconda

EXTRUDED SHAPES

COPPER · BRASS · BRONZE AND SPECIAL COPPER ALLOYS

WHICH CARBURIZING BOX
Cut Fuel Costs $40 a Heat?

The above is not a case of trick photography. Only the PSC carburizing box is pictured because considerations of propriety made it advisable to omit a photo of one of the old cast boxes which were replaced at such a saving. In addition to lowering the fuel costs, the installation of PSC sheet alloy carburizing boxes also effected substantial labor savings, because they handle easier and faster due to their lighter weight.

Weigh Up to 2/3 Less. Save Time and Fuel

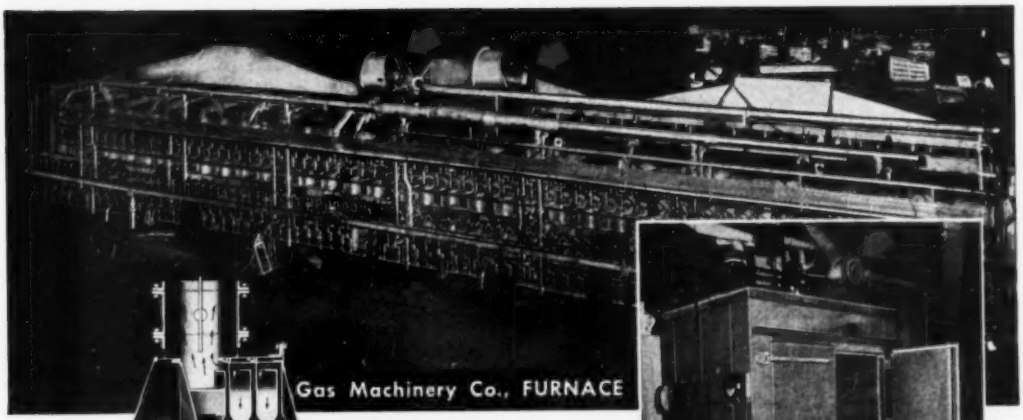
This installation graphically illustrates the fuel economies which PSC carburizing boxes effect. To heat the metal itself of the old cast boxes was costing $60 a furnace cycle. Since the PSC sheet alloy boxes weigh 2/3 less a loading of them could be heated for roughly $40 less. This sizable saving, multiplied by the number of heats in a year, developed into a real slash in production costs for the department. Today 80% of the nation's heat treaters use PSC carburizing boxes. Plant records show they last 2 to 20 times longer. As pioneers of light-weight sheet alloy heat treating equipment, we offer you a wealth of experienced engineering assistance. PSC units are furnished in any size, design or metal specification, and for every purpose: annealing and carburizing boxes, covers, baskets, racks, tubes, retorts, etc. Send blue prints or write as to your needs.

The PRESSED STEEL Co. PSC

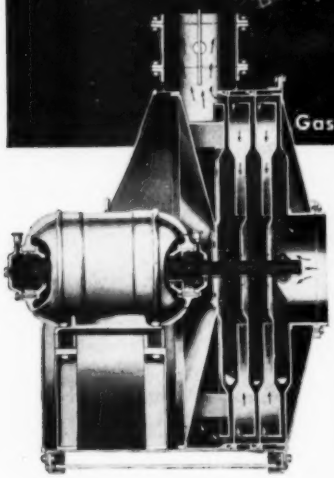
THE PRESSED STEEL COMPANY
of WILKES-BARRE, PENNSYLVANIA

Industrial Equipment of Heat and Corrosion Resistant WEIGHT-SAVING *Sheet Alloys*

☆ ☆ ☆ OFFICES IN PRINCIPAL CITIES ☆ ☆ ☆



Gas Machinery Co., FURNACE



Young Bros., OVEN

THE SPENCER TURBO IS *Recommended*

BY MANUFACTURERS OF

DEHUMIDIFIERS
DISHWASHERS
FLOTATION EQUIPMENT
FURNACES
GAS BOOSTERS
GAS MIXERS
OVENS
PNEUMATIC TUBE SYSTEMS
SPRAYING MACHINES

In many industrial operations the air supply is the heart of the equipment. For more than thirty years Furnace and Oven Manufacturers have insured equipment performance by recommending Spencer Turbos. Today, more than 35 manufacturers of heat treating and foundry equipment specify Spencer.

In addition, a growing list of builders of special machinery are incorporating Spencer Turbos in their designs. A few examples are listed at the right.

There is nothing mysterious about this preference. The Spencer Turbo is a simple, light weight, all metal, quiet running machine with wide clearances and only two bearings to grease. It repeatedly demonstrates repair costs of less than a dollar per machine per year.

Standard sizes from 35 to 20,000 cu. ft.; ⅓ to 800 HP; 8 oz. to 10 lbs. Single or multi-stage, two or four bearing. Special gas-tight and non-corrosive construction available.

ASK FOR THESE BULLETINS

TECHNICAL BULLETIN	No. 126
DATA BOOK	No. 107
GAS BOOSTERS	No. 109
FOUR BEARING	No. 110
BLAST GATES	No. 122
FOUNDRIES	No. 112

393

SPENCER HARTFORD

THE SPENCER TURBINE COMPANY • HARTFORD 6, CONN.

TURBO-COMPRESSORS

ROTARY AUTOMATICS • SEMI-AUTOMATICS • STRAIGHT LINE AUTOMATICS

• FOR HIGH PRODUCTION POLISHING AND BUFFING •

ACME Semi-Automatics

...a family of PROVED PRODUCERS!

★ ACME Semi-Automatic Polishing and Buffing machines are a versatile family that have demonstrated their value in cutting finishing costs in industry for nearly half a century.

Eight basic types of machine having characteristics specially suited to specific types of work are given an unusual range and adaptability through various arrangements of adjustable floating head polishing and buffing lathes, belt head units, tailstocks, air pullback units with or without timer control, plain or automatic-type chucks, and holding fixtures.

ACME Semi-Automatics are turning in high output with low man-hour cost in many leading industrial plants. These machines are dependable and are furnished with fixtures and special arrangements to meet the requirements of the specific part to be finished. Their popularity is founded on a long record of performance under varied production requirements and on a great variety of jobs.

Visit our booth No. 826, Oct. 17 through 21, National Metal Exposition, Cleveland, Ohio.

★ ACME *"Semis" deliver the goods under long hours of production!*

SPECIAL MACHINERY AMC AUTOMATIC BUFFING MACHINES

ACME Manufacturing Co.

1645 HOWARD ST. DETROIT 16, MICH.

Builders OF AUTOMATIC POLISHING AND BUFFING MACHINES FOR OVER 30 YEARS

AUTOMATIC or hand polishing . . . mounting . . . cutting-off specimens . . . all require the best in equipment and accessories.

Precision offers you a source of supply and an engineering staff to help you in solving your particular Metallurgical problems. From cut-off wheels to grind-polishing powders, a constancy is maintained in order that you may not only get the best possible results, but, **results which can be duplicated!**

A copy of our Metallurgical Catalog will provide you with information which will be most helpful. Write for your copy today.

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Laboratory Supply Dealers

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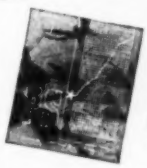


PRECISION PS SCIENTIFIC

Please! A copy of your Metallurgical Catalog No. 860Q

Company_____
Address_____
City & State_____
Individual (Title)_____

Courtesy Hyscore Arms Co., Brooklyn, N.Y.

Does This Tubing Idea Hit Your Target?

Aiming for an inventory reduction . . . lower production costs . . . or a sales edge on competition? Try sighting along the tubing idea in this target pistol.

This airgun is accurate within a $\frac{3}{4}$" bulls-eye on a 20' test range. It is powered by a hardened piston which, in only a 2" stroke, develops enough energy to slam a .22 cal. pellet through a $\frac{3}{8}$" pine board.

Note the ingenious design . . . how the entire gun barrel, from piston chamber to gunsight, is cold-swaged from a single piece of seamless steel tubing—a considerable saving over composite construction. The barrel tubing is supplied by Frasse with a special I. D. cylinder finish, to close tolerances—and provides a leakless air-seal for the piston—*without the expense of further machining.* Completion of the barrel requires 15 separate fabricating operations, from swaging and broaching through milling and threading—an exacting application made possible only with quality tubing and engineering teamwork.

Frasse, a leading distributor of steel tubing, stocks a wide range of immediately available carbon, alloy and stainless analyses to work from. But equally available, and equally useful, are Frasse engineering facilities to help you use tubing to your economical advantage. *Call Peter A. FRASSE and Co., Inc., 17 Grand St., New York 13, N. Y. (Walker 5-2200) • 3911 Wissahickon Ave., Philadelphia 29, Pa. (Baldwin 9-9900) • 50 Exchange St., Buffalo 3, N. Y. (Washington 2000) • Jersey City • Syracuse • Hartford • Rochester • Baltimore*

FRASSE

your best bet for Steel Tubing

Seamless and Welded Mechanical Tubing • Aircraft, Condenser and Pressure Tubes • Stainless Tubing, Seamless and Welded • Stainless Pipe, Valves and Fittings

NEW! For Stainless Pipe and Tube Users!

This new 24 page Frasse manual is brimful of useful data on stainless steel tubular products. Includes type characteristics, physical properties, fabricating data, tolerances, standard finishes, corrosion resistance, and similar essential information. Invaluable for reference if you're working with stainless tube or pipe. Send the coupon for your free copy today.

Peter A. Frasse and Co., Inc. 37K
17 Grand Street, New York 13, N. Y.

Please send me a complimentary copy of your new handbook on stainless steel, pipe and tubing.

Name: ..... Title: .....

Firm: .....

Address: .....

TO STUDY... AND TO LEARN

September—young America is returning to schools and colleges all over the land—to study and to learn—to be armed with knowledge for the struggle with the future.

Here, at Wisconsin Steel, we too, are studying and learning; new techniques to make finer steel, new and better ways to serve our customers—these are our first considerations.

We invite you to call on us when you are ready to place your next order. You will find that Wisconsin Steel has learned to serve its customers well. Our sales and technical staffs are ready to study and fill your needs.

WISCONSIN STEEL COMPANY, Affiliate of INTERNATIONAL HARVESTER COMPANY
180 North Michigan Avenue • Chicago 1, Illinois

WISCONSIN STEEL

FOR BETTER PERFORMANCE UNDER VIBRATION

Consider These GRAY IRON Characteristics:

- Castability
- Rigidity
- Low Notch Sensitivity
- Wear Resistance
- Heat Resistance
- Corrosion Resistance
- Machinability
- VIBRATION ABSORPTION
- Durability
- Wide Strength Range

Write for free booklet, "GRAY IRON—Its Mechanical and Engineering Characteristics, and Details for Designing Cast Components".

Call it Vibration Absorption or call it Damping Capacity—by either name it's a very important consideration in many applications. It makes for quiet operation. Lack of such capacity may result in failure due to critical vibration.

Gray Iron has exceptionally high damping capacity, higher than any of the other common engineering materials . . . up to *ten times* that of any other ferrous metal.

The practical usefulness, therefore, of a part subject to vibration stresses, may be *greater when it is made of Gray Iron* than when it is made of what might commonly be regarded as a much stronger material, but which has *low damping capacity*.

Are you taking full advantage of the unmatched combination of useful properties offered by Gray Iron? Have you considered its ultimate economy?

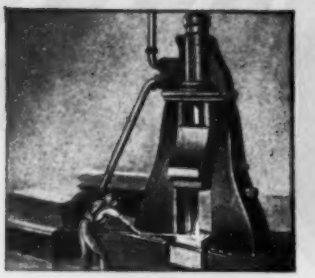
Make It Better with Gray Iron

Second largest industry in the metal-working field

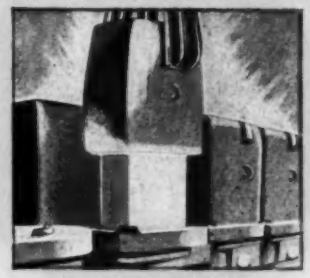
GRAY IRON FOUNDERS' SOCIETY, INC.

NATIONAL CITY-E. 6th BLDG., CLEVELAND 14, OHIO

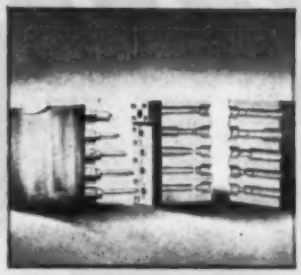
When the HEAT'S on...



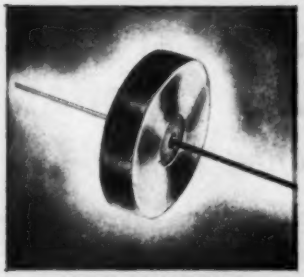
FORGING



STEEL INGOT STRIPPING

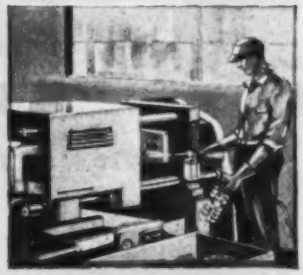


DEEP PIERCING



WIRE DRAWING

STRETCH FORMING



DIE CASTING

"dag" Colloidal Graphite Keeps 'em Lubricated!

At high temperatures . . . 400°F. and up, where ordinary lubricants begin to fail . . . **"dag"** colloidal graphite dispersions lick friction and keep parts lubricated for action.

"dag" colloidal graphite is not just ordinary graphite. It is graphite which has been processed scientifically so that its particles are usually less than .000039 inch in diameter!

This means that when colloidal graphite is applied to the friction surfaces of metal it leaves a lubricating film so thin that even the most sensitive gages cannot detect it. The film is many times more durable than an oil film. It provides the metal with a graphoid surface that has an extremely low coefficent of friction, that resists oxidation, and that will function at temperatures far above the burning point of oil.

Acheson Colloids engineers are anxious to help you with your lubrication problem. Call the local representative, or mail the coupon TODAY for more information on **"dag"** colloidal graphite dispersions.

Acheson Colloids Corporation, Port Huron, Mich.; Boston; New York; Philadelphia; Pittsburgh; Cleveland; Detroit; Chicago; St. Louis; Los Angeles; San Francisco; Toronto.

dag COLLOIDS

ACHESON COLLOIDS CORPORATION
Port Huron, Michigan

☐ Send me more information

☐ Send a sales engineer at my convenience

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J-10

Seamless Tubing Production Line at

THE BABCOCK & WILCOX TUBE COMPANY

Demonstrates Advantages of Speed-Heating with GAS

CONTINUOUS REHEATING of seamless tubing, at production speeds integrated with piercing-mill and sizing-mill capacities, demonstrates some of the important advantages of high-speed heating with GAS.

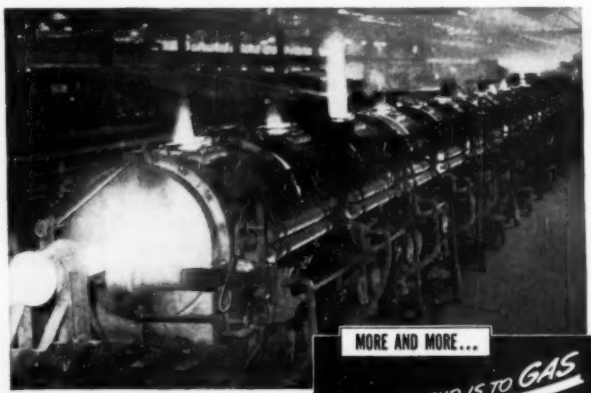
Many types of carbon, alloy and stainless steels are used in the manufacture of seamless tubing at The Babcock & Wilcox Tube Company. During the early stages of tube formation the tubes drop in temperature before entering the sizing mill. The modern Gas-fired units in the Beaver Falls, Pennsylvania, plant perform this reheating operation at speeds up to 162 FPM for 6-inch tubing.

Another important factor is the precise temperature control which permits adjustment of production speeds to compensate for delivery from the rolling mill or the requirements of the sizing mill. In addition, the automatic controllability of GAS permits immediate adjustment of temperatures for any type of alloy tubing.

Some of the results, attributed to this high speed GAS heating system by production executives of The Babcock & Wilcox Tube Company include—

- **fuel costs for reheating reduced 63% per ton**
- **output increased over 10% per hour**
- **product improved by absolute uniformity of heating**
- **maintenance costs reduced due to equipment simplicity**

The versatility of GAS for high-speed heating has been demonstrated in all type of production operations. It's always well to keep in touch with the latest developments in effective utilization of GAS.



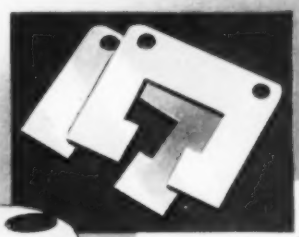
Battery of twelve continuous Gas-fired Selas heating units in which seamless tubes, on way to sizing mill, are reheated from 1300F to 1900F and above.

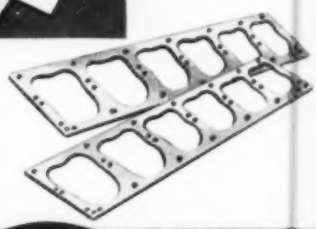
AMERICAN GAS ASSOCIATION

420 LEXINGTON AVENUE · NEW YORK 17, NEW YORK

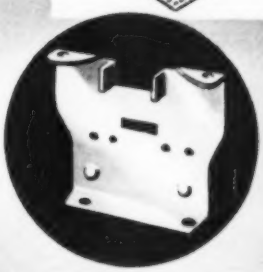
Weirzin

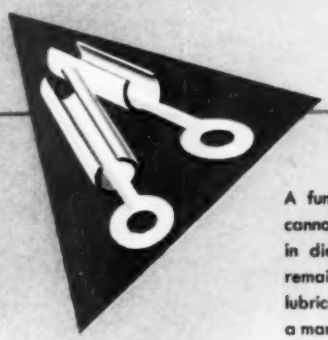
ELECTROLYTIC ZINC-COATED SHEETS AND STRIP





DIES LAST AND LAST . . .





A fundamental advantage possessed by Weirzin—one you cannot afford to ignore—is that it can effect important savings in die maintenance costs. Its tight electrolytic zinc coating remains intact in drawing operations, serving like a film of lubricant, to prolong the useful life of the dies. For example, a manufacturer reports that his usual production run of 100,000 pieces per set of dies, using ordinary carbon steel, was increased to 400,000 pieces when he adopted Weirzin.

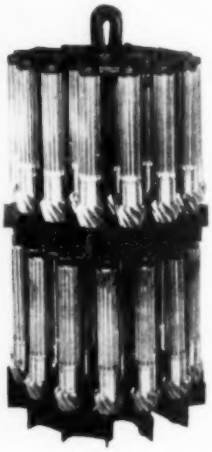
Weirzin effects other appreciable savings in manufacturing, too. Sheets and coils require no pickling or buffing—and bonderized Weirzin products need no primer under paint.

WEIRTON STEEL CO.

WEIRTON, W. VA., *Sales Offices in Principal Cities*

Division of **NATIONAL STEEL CORPORATION,** *Executive Offices, Pittsburgh, Pa.*

JOB PROVEN IN INDUSTRY



ENGINEERED FOR THE JOB:

48 PINIONS — 1248 lbs. WEIGHT — 317 lbs. ALLOY

This CHRISTMAS TREE pit-type carburizing fixture was designed for use at Allis-Chalmers Mfg. Co., Springfield, Illinois, to give them *maximum* loading of parts with *minimum* weight of alloy. Entire load and alloy fixture quenched direct from carburizing temperature into oil.

NOTE THESE OUTSTANDING CHARACTERISTICS:

- 4 to 1 loading ratio providing optimum production.
- Lifting eye cast as an integral part of the post eliminating premature failures which result from conventional welded-in pins.
- Elimination of circumferential ribs which tear themselves apart.
- Uniform sections throughout to provide perfect quenching characteristics.
- Full radii of rib surfaces to prevent incipient cracks encountered with square edges.
- Versatility of loading.
- Provides uniform quenching of parts and minimum distortion.
- ANALYSIS TOP QUALITY 38 NI—18 CR.

Every alloy application must be ENGINEERED for the job—plus the employment of the most advanced foundry technique—to assure the user maximum life—minimum operating expense.

HEAT RESISTANT CASTINGS

ACCOLOY

STAINLESS STEEL CASTINGS

FURNACE PARTS

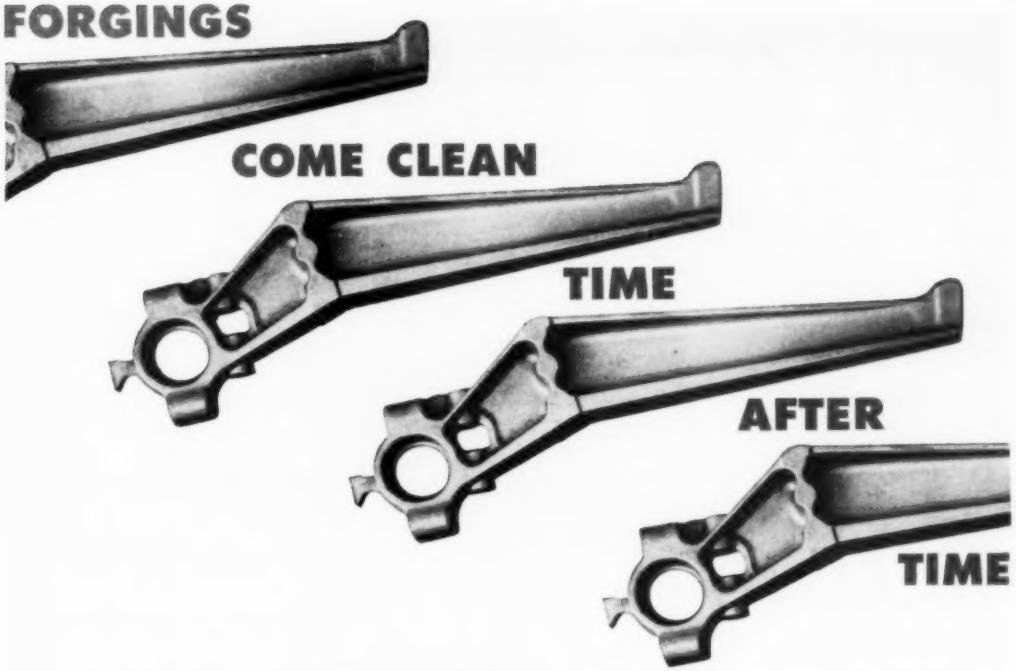
Muffles • Retorts • Belts • Chain • Roller Rails • Trays & Fixtures • Carburizing Boxes • Salt Pots

ALLOY ENGINEERING AND CASTING COMPANY

Alloy Casting Co. (Division)

Champaign, Illinois

ENGINEERING OFFICES IN PRINCIPAL CITIES



. . . thanks to TIMKEN® forging bar quality

CLEAN, perfect forgings, of uniform quality all the way through, are the result of using Timken® forging bars. You get the same dependable performance from bar after bar, heat after heat.

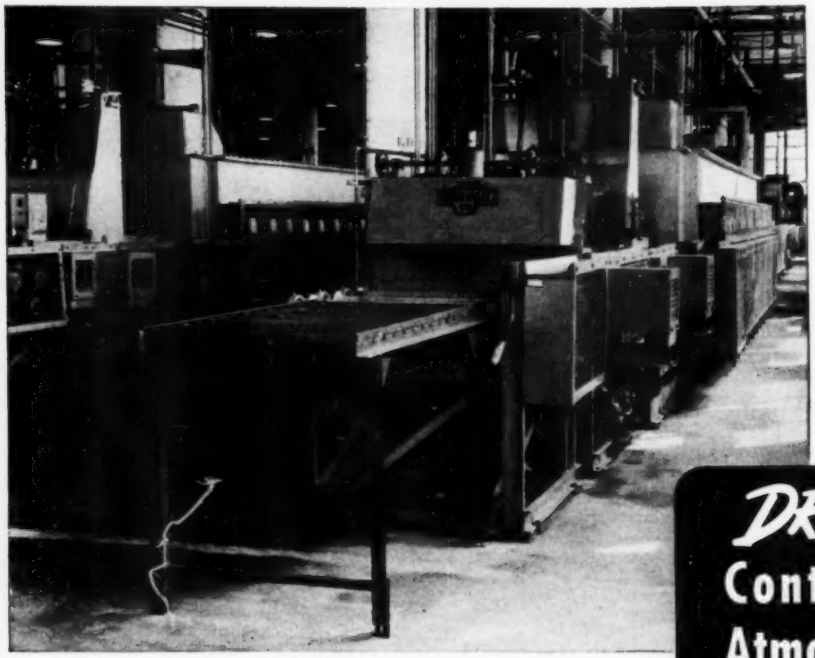
Timken steels offer uniform behavior in forging, uniform response to heat treatment, and uniform machining qualities. This means that you can standardize shop practices, have fewer delays and rejects, and turn out consistently better products at top production every month!

The uniformity of Timken steel is due to rigid quality control by the most precise methods known. Many of the special practices employed in the Timken plant are only possible in such a large, flexible specialty mill. Into the making of every bar goes the skill and knowledge that comes of years of experience as the world's largest producer of specialty alloy steels.

Our Technical Staff will be glad to recommend the correct analysis for your particular requirements. Ask for our 112-page book, "Evaluating the Forgeability of Steels". The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO".

50th birthday of the company whose products you know by the trade-mark: TIMKEN

Specialists in alloy steel—including hot rolled and cold finished alloy steel bars—a complete range of stainless, graphitic and standard tool analyses—and alloy and stainless seamless steel tubing



Two (2) 330 KW
Atmosphere Roller
Hearth Furnaces

DREVER Controlled Atmosphere ROLLER HEARTH FURNACES

for Bright Annealing, Clean Hardening, Sintering, and Brazing

Drever Atmosphere Roller Hearth Furnaces combine the speed and efficient material handling of the roller hearth with the advanced engineering design of Drever controlled atmosphere furnaces.

Drever Roller Hearth installations include all types of firing, a wide range of atmosphere; and sizes to meet specific requirements.

Our Engineering Department will be glad to show you the inherent advantages of Atmosphere Roller Hearth Furnaces.

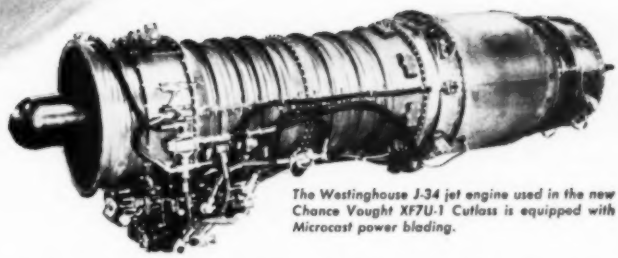
DREVER CO.

790 E. VENANGO ST., PHILA. 34, PENNA.

CONTINUOUS FURNACE LINES, HEAT TREATING FURNACES, DESCALING & ATMOSPHERE EQUIPMENT

NEW YORK & NEW ENGLAND—GERALD B. DUFF, 68 CLINTON AVE., NEWARK 5, N. J.
W. PENNA., W. N. Y. and OHIO—H. C. BOSTWICK, 3277 KENMORE RD., CLEVELAND 22, OHIO
IOWA, MINN. & WIS.—WALTER G. BARSTOW, 1302 FIFTH AVE. SOUTH, MINN. 4, MINN.

MICROCASTINGS...Basic Components in Jet Turbines



The Westinghouse J-34 jet engine used in the new Chance Vought XF7U-1 Cutlass is equipped with Microcast power blading.

The Microcast Process has proven ideal for the specialized production requirements of power blading for jet turbine, gas turbine, and the other revolutionary new types of aircraft power development units.

During the war years, Microcast was selected as the production process for millions of turbo-supercharger blades. These blades as well as the blades used today in aircraft turbine units must withstand extreme thermal and dynamic stresses. They require the use of the high melting point, non-machineable and non-forgeable alloys. The answer to economical quantity production of these blades is Microcast, for Microcastings as cast are sound, smooth, and dimensionally uniform. They require virtually no machining.

Perhaps Austenal's experience can help you, too.

WRITE FOR BOOKLET. More complete information on Microcast is contained in a new 16-page booklet published by Austenal Laboratories, Inc., originators of the Microcast Process. This valuable booklet is fully illustrated and describes many applications for Microcasting as well as a step-by-step description of the process itself. Write for your copy today.

The name MICROCAST is a registered trademark of Austenal Laboratories, Inc.

MICROCAST PRECISION CASTINGS PROCESS

MICROCAST

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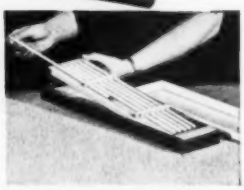
MICROCAST DIVISION
AUSTENAL LABORATORIES, INC.
224 East 39th Street • New York 16, New York
715 East 69th Place • Chicago 37, Illinois

Ahead in packaging, too!

TAG A.S.T.M. and Standard Grade Thermometers

To remove thermometers, simply raise end of box platform.



Thermometers readily slide in or out of spacing retainers.

TAG—oldest name in the business, with its new WESTON affiliation and new, modern plant, now reasserts its leadership in the field. Makers of the highest grade thermometers since 1769, TAG is *first* to develop this unique, improved thermometer packaging*. The compact, handy design means new convenience, less cumbersome handling for you. Result: reduced breakage, faster inspection, easier testing and uniform stocking.

Complete specifications on each box label. Available in lots of three or six to a box. Comprehensive stocks. Order from your laboratory supply dealer, or direct from us. Catalog 1100 lists and describes the complete line of TAG Thermometers and Hydrometers and contains useful Fahrenheit-Centigrade conversion tables. Just write for it.

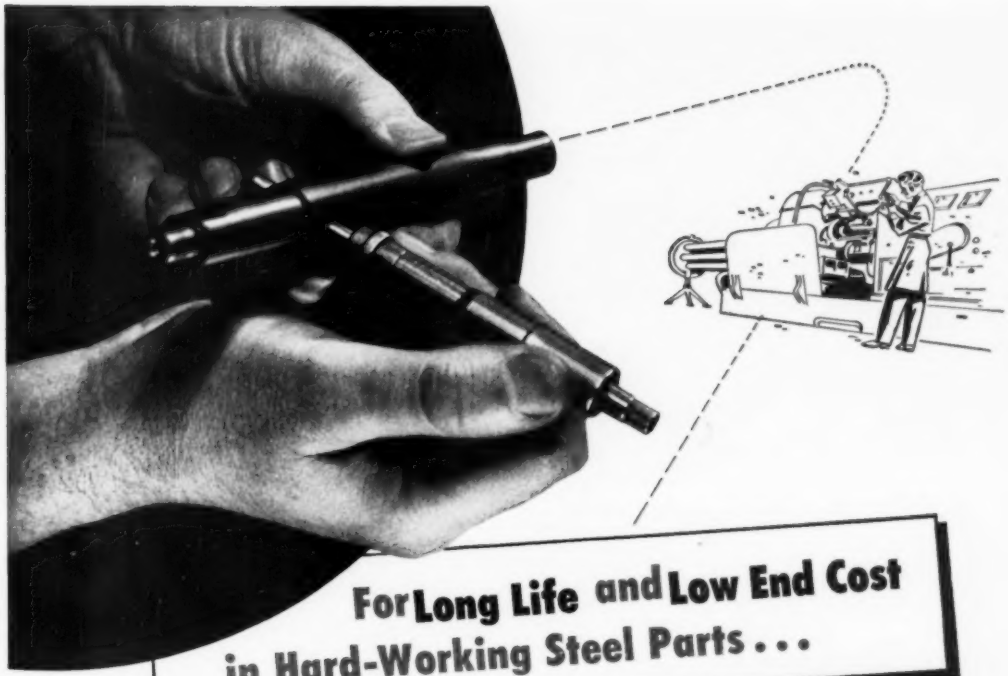
*Patent Pending

C. J. Tagliabue Corporation (N. J.)

Subsidiary of WESTON ELECTRICAL INSTRUMENT CORPORATION

591 Frelinghuysen Avenue, Newark 5, N. J. Representatives in all Principal Cities

TAG



For Long Life and Low End Cost in Hard-Working Steel Parts . . .

. . . use *Republic* Cold Drawn Alloy Steel Bars

LONG LIFE—Because Republic Alloy Steels provide these long-proved advantages: (1) High strength to carry heavy loads; (2) Toughness to withstand severe shock and strain; (3) Uniform response to hardening treatment that produces hard bearing areas.

LOW END COST—(1) Because the long life of steel parts made of Republic Alloy Steels means fewer repairs and replacements—less maintenance expense—more operating time and less down-time. (2) Because these bars provide the UNIFORM MACHINABILITY, accuracy of section, close tolerances and fine surface finish for which Union Cold Drawn Products are so well known—and which means lowest possible parts production costs.

Republic Cold Drawn Alloy Steel Bars are available in all popular analyses, in standard shapes and sizes, furnace treated as you desire—annealed, normalized, spheroidized, stress relieved or carbon corrected. Republic metallurgists are ready to help you get the results you need. Write for further information.

REPUBLIC STEEL CORPORATION
Alloy Steel Division • Massillon, Ohio
GENERAL OFFICES • CLEVELAND 1, OHIO
Export Department: Chrysler Building, New York 17, N.Y.

Republic COLD DRAWN
REPUBLIC STEEL
ALLOY STEEL BARS

Other Republic Products include Carbon and Stainless Steels—Sheets, Strip, Plates, Pipe, Bars, Wire, Pig Iron, Bolts and Nuts, Tubing

NEW BUEHLER-WAISMAN

Electro-Polisher

—produces a beautifully polished surface on practically all metals and alloys—represents a new revolutionary approach for metallurgical specimen preparation.

- ★ The new Buehler-Waisman Electro-Polisher is a sturdy, stream-lined, laboratory instrument, designed for efficiency in performance.
- ★ Ferrous and non-ferrous metals can be prepared with equal speed and simplicity. Both large and small samples are readily accommodated.
- ★ Simple to operate—does not require an expert technician to produce good specimens.
- ★ Speed in operation—various specimens may be prepared in a fraction of the usual time required.
- ★ Economical—only a small amount of non-explosive chemical required.
- ★ Results are dependable — scratch free specimens, uniformly etched for true structure examination.

THE BUEHLER LINE OF SPECIMEN PREPARATION EQUIPMENT INCLUDES—CUT-OFF MACHINES • SPECIMEN MOUNT PRESSES • POWER GRINDERS • EMERY PAPER GRINDERS • HAND GRINDERS • BELT SURFACERS • MECHANICAL AND ELECTRO POLISHERS • POLISHING CLOTHS • POLISHING ABRASIVES.

Buehler Ltd. METALLURGICAL APPARATUS
A PARTNERSHIP
165 West Wacker Drive, Chicago 1, Illinois

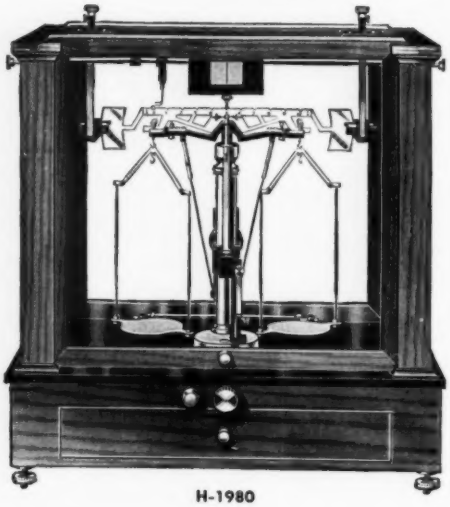
"Have used **Pittsburgh Steel Wire**
successfully for over 25 years
with great satisfaction"
says **The Ferry Cap & Set Screw Co.**

You will find, like The Ferry Cap & Set Screw Co., and many others, that Pittsburgh Steel Wire works easily in your cold headers and gives you economical trouble-free operation in your plant. Pittsburgh Steel Wire has uniform size to feed easily into dies—the ductility to form readily in upsetting, extruding, roll threading, bending or flattening operations. The inherent quality of Pittsburgh Steel Wire gives you assurance that your products will be sound and tough. It will please your operating men and help keep your customers happy. Specify Pittsburgh Steel Wire for all your operations.

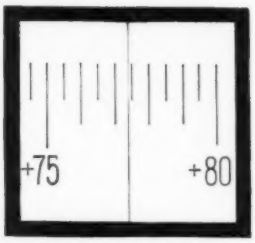
Pittsburgh Steel Company
Pittsburgh 30, Pa.
JOHNSON STEEL & WIRE COMPANY, INC.
Worcester, Mass.

Projection Reading Analytical Balance

Rapid Automatic Weighings from 1/10 mg. to 100 mg., plus and minus.



H-1980



View of glass screen showing center vertical line indicating a reading of + 0774 gram.

Adjustment of zero (0) is instantly made by moving the center vertical line to the left or right by means of an adjusting screw on the left outside of balance case near the top.

You'll save time and insure accurate results by using the Christian Becker Projection Reading Analytical Balance. This fine instrument makes precise weighings rapidly and automatically from 1/10 mg. to 100 mg. (plus and minus).

General Specifications

Capacity . . . . . 200 grams.

Beam . . . . . $17\frac{1}{2}$ cm. (7 in.) long, sawed from special aluminum alloy, great tensile strength and uniform density.

Beam graduated left to right, 0 to 1 gram in 0.1 gram graduations (*no weights below 1 gram required*).

Beam weight is rapidly moved from one notch to another by means of a carrier operated outside of case.

Knife Edges . . . . . Agate.

Bearings . . . . . Agate Planes.

Releasing Mechanism: Beam Arrest

The special construction of the beam arrest not only insures the positive alignment of the agate edges with their respective bearings, but is so designed that the center agate knife edge is directly over the center of the column. This is of great importance when the balance is loaded to full capacity and where the greatest precision is required. The beam arrest arms and the beam being pivoted about a common axis, the supporting points of the arrest arms move through the same arc as the supporting points of the beam, so that contact between edge and bearing always remains the same, thus the acme of balance construction is reached, the shifting of the end bearings with the consequent dulling of the agate edges being precluded.

Rider Carrier . . . Vertical lift, insures accurate alignment, in all positions, of lifting hook with the beam.

Pans . . . Stainless steel. 3 in. diam.

Bows . . . Nickel silver with straight sides, to accommodate large drying tubes, etc., $4\frac{1}{4}$ x $8\frac{1}{4}$ in. high inside.

Pan Arrest . . . Independent arrest for pans with stop.

Case . . . Polished mahogany with glass sides and top, front sliding door counterpoised, with drawer. Mounted on black plate glass. With level and leveling screws.

Dimensions overall

$19\frac{1}{4}$ in. long, $11\frac{3}{4}$ in. deep, 20 in. high.

Price, without weights. For 110 volts A.C., 60 cycles. Ready to attach to light socket . . **H-1980—$750.00**

HARSHAW

HARSHAW SCIENTIFIC

DIVISION OF THE HARSHAW CHEMICAL CO.

CLEVELAND 6, OHIO

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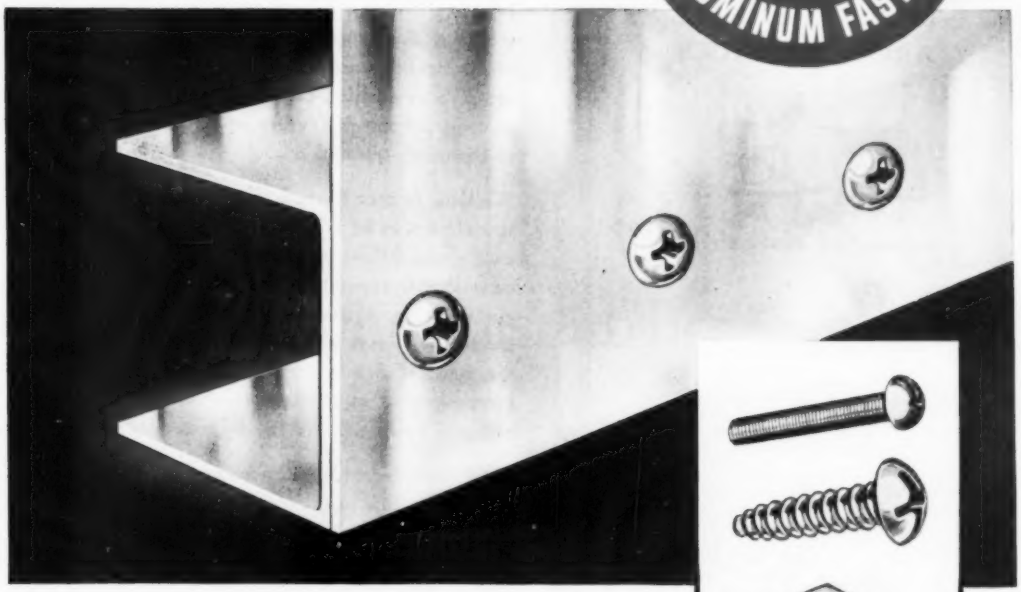
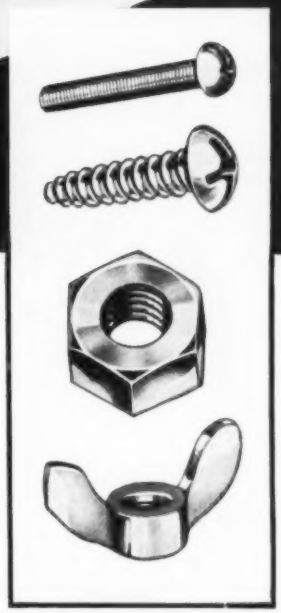
THE JOINTS STAY TIGHT WHEN YOU





Use Alcoa Aluminum Sheet Metal Screws

Use of Alcoa Aluminum Fasteners will prevent galvanic corrosion that can result when dissimilar metal screws are used to fasten aluminum assemblies. They help joints stay strong and tight.

Alcoa Fasteners resist common corrosion, too—won't rust red or stain adjacent surfaces. And their low cost will amaze you.

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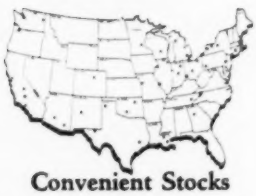

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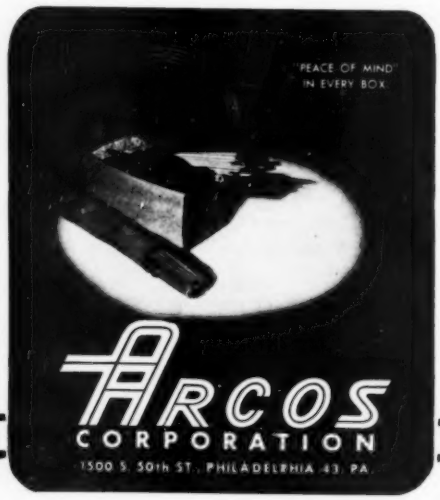

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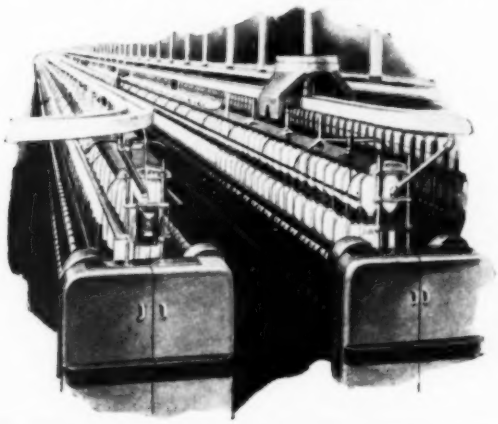

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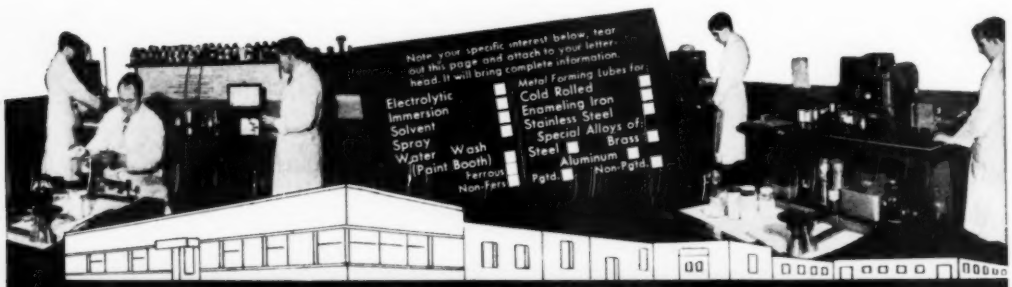

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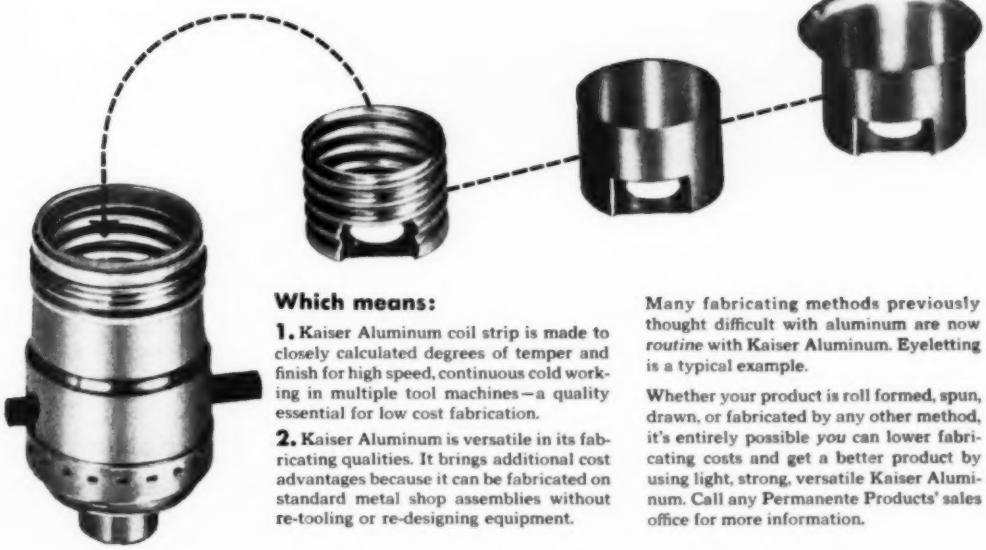

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September, 1949

Volume 56, No. 3

Metal Progress

Ernest E. Thum, Editor
Taylor Lyman, Associate Editor

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Cover Design

A friendly critic has said that a description of the front cover would be in order, now and then. For example, he asks of the present design (by Eileen Israel): "Is it a television set with an aerial?" No, it is an extensometer for a creep test (red ink) with a line diagram suggesting the electrical circuits for the indicator.

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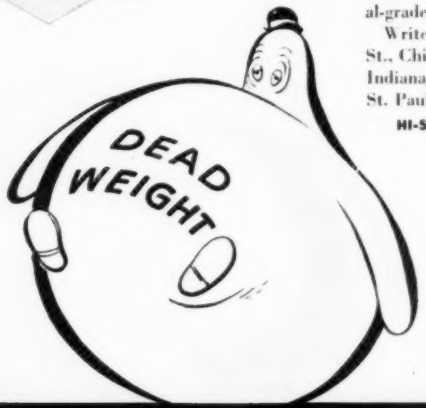

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THE LOW-ALLOY HIGH-STRENGTH STEEL

Trends in High-Strength Wrought Aluminum Alloys

By W. B. F. Mackay
Instructor in Metallography
and R. L. Dowdell
Head, Dept. of Metallurgy
University of Minnesota

These new high-strength alloys are found to have approximately equal compressive and tensile yield strengths. Thus, they may be used very effectively as compression members in addition to their old role primarily as tension members. These new engineering requirements have given great impetus to the development of new high-strength aluminum alloys.

WITHIN the realm of wrought aluminum alloys for highly stressed applications there is a continual long-range desire for the development of materials with higher mechanical properties, particularly for the aircraft and transportation industries. Many factors such as cost, workability, and corrosion resistance, enter the picture, but the main objective is a light alloy with its strength in the range of steel's.

Recent years have witnessed a gradual change in the engineering viewpoint in regard to the mechanical properties demanded of structural materials.[1] [References will be found on p. 404.] This fact is particularly evident in connection with structures such as airframes.[2] Originally, great emphasis was placed on elongation, impact strength, resistance to corrosion and the ultimate tensile strength. The modern aircraft designer is now often willing to accept a much lower elongation and less spread between the ultimate tensile strength and the tensile yield strength. (Heat treating the newer types of high-strength wrought aluminum alloys frequently imparts a relatively greater increase in the yield strength than the ultimate strength is increased.) He is greatly concerned with the compressive yield strength, which formerly was not considered of much account. Many of these changes in requirements have been demanded by larger aircraft and the use of thicker structural sections in air foils.

Heat Treatment—Aluminum alloys are usually classified under two main headings, the casting alloys and the wrought alloys. Each of these two principal divisions may be further subdivided into the non-heat-treatable alloys and the heat-treatable alloys.[3] Some common wrought alloys of the non-heat-treatable type are listed in the left frame of the accompanying diagram (p. 332). It will be noticed that they are all relatively low in strength and contain very small amounts of alloying agents as compared to the heat-treatable alloys in the remaining three frames.[4] These not-heat-treatable alloys, not being responsive in any way, have to rely on small alloy additions and cold working to increase their strength. Though these alloys possess many desirable properties and constitute by far the highest annual tonnage of wrought aluminum alloys produced, they have been replaced by the heat-treatable alloys in applications requiring high strength.

The heat-treatable wrought aluminum alloys, such as those shown in the diagram, depend on a precipitation hardening treatment to develop their maximum mechanical properties. This generally consists of a two-stage operation — first a solution heat treatment followed by a quench, and secondly an aging or (as sometimes called) a "precipitation heat treatment". The purpose of the solution treatment is to put all constituents into a homogeneous solid solution with the aluminum, by heating for a sufficient time at a temperature not far below the melting point of the alloy's lowest melting point constituent. Slow cooling from solution treatment temperatures would permit an

undesirable precipitation, as the solubility of the alloying agents in aluminum decreases markedly as room temperature is approached. In practice, therefore, a rapid quench is employed to avoid this precipitation with its resultant loss in mechanical properties. The room-temperature condition after the quench is a supersaturated solid solution; this is not stable and will tend to precipitate the excess constituents. The actual rate of precipitation depends (other than on temperature) largely on the chemical composition of the alloy under consideration.

The next step is to produce the desired amount of precipitation to impart *maximum* mechanical properties. Certain alloys such as 17S are called "naturally aging" as they will automatically attain full strength within four to six days at room temperature. Most of the higher-strength alloys, however, require a few hours at a slightly elevated temperature (240 to 380° F.) to achieve maximum properties, and these alloys are referred to as "artificially aging".[5] Many of these same artificially aging alloys will partially age at room temperature if allowed sufficient time, but the increased atomic mobility obtained by moderate heating greatly reduces the time required and usually gives higher physicals.

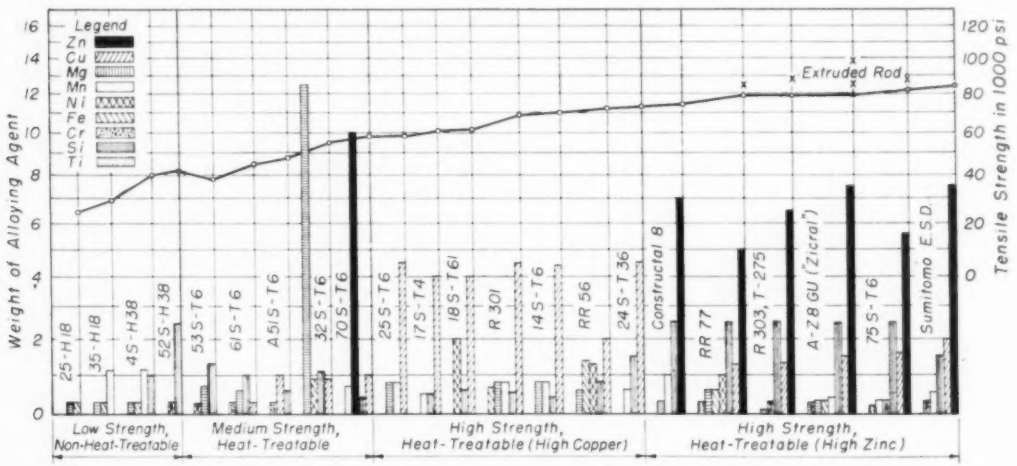
At the risk of oversimplifying an extremely complex and controversial subject, it may be said that heat treatment of aluminum alloys seeks to attain the correct disposal of a critically-sized particle which will give maximum physical and mechanical properties. Various theories have been advanced to explain the mechanism of age hardening; essentially, they all attribute the hardening to increased resistance to slip along the crystallographic planes of the alloy.

Historical

About 40 years ago, Alfred Wilm of Germany published his now classic work on aluminum alloys containing copper and magnesium.[6] This article, describing the solution and precipitation treatment of aluminum alloys, not only opened up the entire field of age hardening, but also gave "duralumin" to the world, the first of the high-strength wrought aluminum alloys which were dominant through World War I and into the early 1930's. This alloy, known more commonly on the American continent as 17S, is still used — though it has been replaced in the higher-strength applications by modified versions such as 24S, R301, and other very similar alloys.[7]

The 1930's witnessed the introduction of many slightly modified duralumin (17S) alloys, such as the widely used 24S. This was the basic high-strength alloy in production throughout World War II and is still very extensively used. Fairly recently, increased mechanical properties have been obtained for certain applications by subjecting this alloy to a small amount of cold work between the solution and the aging treatments, and then artificially aging it. (It heretofore was considered only as naturally aging.[8])

During 1943 and 1944 a new series of very



Tensile Strength and Nominal Chemical Composition of Some Wrought Aluminum Alloys. Small amounts of certain elements such as iron and silicon are not always indicated. Strength values are typical, not guaranteed minimum. Most values are for sheet specimens; extrusions are indicated by ×

high-strength wrought aluminum alloys began to compete with 24S in America for applications where higher strengths were of prime importance. They were of a complex copper-magnesium-zinc-aluminum type known as 75S (Aluminum Co. of America)[9] and R303 (Reynolds Metals Co.).[10] Somewhat similar alloys have been developed and used abroad, notably in Germany, Great Britain and Japan.

The remarkable mechanical properties of these new Cu-Mg-Zn-Al alloys (right frame of the diagram) which are gradually superseding the older Cu-Mg-Al alloys (third frame) have been well known to light alloy metallurgists for many years. Unfortunately, those possessing the most interesting mechanical properties confronted early investigators with a number of complex problems. Their general corrosion resistance was poor, fabrication was difficult and their susceptibility to stress-corrosion cracking remained to be suppressed.

Any metallurgist with a philosophical turn of mind — especially if he is associated with the wrought aluminum business, either as a producer or consumer — has wondered how much the present alloys can be strengthened, "how much there is in the wood", so to speak. So much time and effort has gone into the perfection of the most recent ones, 75S and R303, that the point of diminishing returns may be upon us. This article considers broadly the present situation, how we got here, and the chances for further substantial progress.

It is interesting to note that during World War I Walter Rosenhain[11] and his co-workers of the National Physical Laboratory in England developed "E" alloy which had an ultimate tensile strength of slightly over 91,000 psi. after certain heat treatments. This Cu-Mg-Zn-Al alloy, containing small amounts of iron, silicon and manganese, was modified slightly to give "F" and "G" alloys, with improved elongation and only slightly reduced strength. "E" alloy was produced commercially during World War I at Cardington, England, by Messrs. Short Bros. (aircraft constructors). The stress-corrosion cracking snag, combined with the forging and rolling problems, apparently put this alloy on the sidelines once the wartime incentive was gone.

The first commercial exploitation of an alloy of this general type in Germany was made during the 1920's. It was an outcome of work done by Sander and Meissner,[12] who published their findings on the Zn-Mg-Al system in 1926. They obtained ultimates as high as 81,800 psi. in their copper-free alloys. The "Constructal" alloys,[13] as they were trade-named, never were widely used, despite their phenomenal strength, due to their susceptibility to stress-corrosion cracking.

Rolls Royce entered this field with a Cu-Mg-Zn-Al mixture which was produced commercially in 1937. This alloy is known as Hiduminium, RR77 or DTD363[14, 15] (British Air Ministry specification). Stress-corrosion cracking was encountered in early applications and restricted its use, but we understood that holding down certain of the alloying additions has largely overcome this problem.

The first high-zinc wrought alloy produced commercially in the United States was Alcoa's 70S. This alloy never received general acceptance. In 1933 a patent was taken out by L. J. Weber[16] for one of the high Cu-Mg-Zn-Al type which possessed a yield strength in excess of 80,000 psi. Further research, however, was necessary on this alloy (75S) before general structural application could be made of it. The U. S. Government was presented with the latest developments of this alloy in 1939 with the result that by the fall of 1943 the stress-corrosion cracking and other difficulties were surmounted and large-scale production was underway.[1] Shortly after that time, the Reynolds Metals Co. was producing a similar alloy called R303.[17]

The Japanese "Sumitomo E.S.D." alloy[18] (see chart) was used during World War II to some extent. Its corrosion resistance was poor and difficulty was experienced in rolling and extruding.

Newcomers in the field since World War II have been few. Other than Alcoa's 76S forging alloy[19] (a modified 75S type) the only new alloy announced to date has been the French Zicral (A-Z8GU).[20] This is a conventional Cu-Mg-Zn-Al alloy with relatively high zinc content; very high mechanical properties are claimed for it.

A study of the chart on page 332 shows that the newer Cu-Mg-Zn-Al type alloys have chemical compositions which are very similar, each to each. It is apparent that metallurgists in various countries have arrived at practically the same conclusions as to the maximum amount of alloying additions permissible without too great a sacrifice of fabricating properties, resistance to stress-corrosion cracking, and other special requirements. (The importance of holding down certain of the major constituents and balancing the composition at the expense of some strength but to the advantage of other desirable properties is confirmed by work being carried out at the University of Minnesota.)

The internal structure of the high Cu-Mg-Zn-Al alloys such as 75S is very complex. In addition to the three principal strengthening agents, chromium and manganese are generally present to inhibit stress-corrosion cracking. Small amounts of iron and silicon are residual from the primary aluminum; usually a grain refiner such as titanium is also introduced. To the above mentioned elements, nickel and others may sometimes be added. To date, despite the work of Fink and Willey,[21] Hume-Rothery and associates[22] and a host of others, no complete set of quaternary diagrams have been accurately drawn up to give us a true picture of the constitution. Thus, as is often the case with new alloys, the production, mechanical testing and use of the product have outpaced a comprehensive and theoretical understanding of the constituents and phases involved.

The Problem

Although experimental alloys have been produced with ultimate tensile strengths of approximately 100,000 psi., the questions arise: "Which known type of alloy may be developed still further?" and "Can distinctly new types be found?" This problem of developing new commercial aluminum alloys possessing tensile strengths above 100,000 psi. is not as simple or clear-cut as might be assumed at first glance. A review of the literature has already indicated that the experimental alloys of 30 years ago possessed strengths fully as high as are obtainable on the market today. Therefore, like most engineering problems, the commercial development of a high-strength aluminum alloy is a compromise among several factors.

The wrought aluminum alloys possess three important characteristics as a constructional material — namely, their light weight, resistance to corrosion, and relatively high strength. It should be realized that any marked improvement in properties in one direction (for example, strength) which is accomplished at the expense of other important properties may very easily eliminate the alloy from commercial acceptance.

Future progress might be expected to appear along two lines: First, a new alloy of different chemical composition might be found; second, new heat treating methods may be devised. Perhaps success will be had by a combination of both.

Consider first a few of the problems encountered in seeking a new alloying addition or combination of currently used additions in a high-strength wrought aluminum alloy:

Specific Gravity — Pure aluminum has a specific gravity of 2.70. This is one of the most desirable properties which aluminum possesses. In alloying pure aluminum to increase its strength, the tendency is to use higher and higher percentages of alloying agents. With the notable exception of magnesium, practically all alloying agents currently used have higher specific gravity than aluminum. Thus, as a new alloy's specific gravity begins to approach 2.8, the additional strength which may be achieved at the expense of lightness must be considered most carefully.

The ideal alloy, therefore, would contain a small amount of alloy additions and those additions should possess a low specific gravity. The following metals are lighter: beryllium, calcium, cesium, lithium, magnesium, potassium, rubidium, scandium, sodium and strontium. All but lithium and magnesium are eliminated when we consider the matter of favorable atomic size factor; they are completely, or else nearly completely, insoluble in aluminum. Lithium has been tried as an alloying element but with little success; it is difficult to use and offers only a negligible improvement in physicals. It was hoped that beryllium might prove promising, despite its high cost and unfavorable size factor. Its very limited solubility and poor physical properties, when alloyed with aluminum, have so far side-tracked it as a possible addition.

The chances of getting an alloy of higher strength and lower weight are not too promising.

Corrosion Resistance — The good corrosion resistance of pure aluminum is often sacrificed to a greater extent than any of the other principal properties when we enter the high-strength field. Cladding and other protective treatments or coverings may safeguard the base alloy to some extent, but a strong alloy with good corrosion resistance would be *most* welcome. The trend toward adding greater amounts of alloy just aggravates the corrosion problem. Some of the best hardening agents are the worst offenders, particularly insofar as intergranular attack is concerned.

Stress-Corrosion Cracking — The curse of all high-strength wrought aluminum alloys, particularly those containing zinc, has been their susceptibility to stress-corrosion cracking. Inability to control this affliction eliminated many of the early high-zinc alloys. Stress-corrosion cracking has been defined as the spontaneous cracking which results from the combined effect of high, prolonged tensile stress and corrosive attack. The combination of high internal plus external stress, both in tension, initiates cracking. Corrosion of an electrochemical nature will accelerate the cracking and, in turn, the stress will expose new paths for further chemical attack. The corrosion action follows localized paths, such as grain boundaries which are anodic to the surrounding metal. The higher-alloyed products, heat treated to give maximum mechanical properties, are in a very susceptible condition. The most successful of the newer high-strength alloys, such as 75S, deliberately sacrifice some strength to avoid stress-corrosion cracking by holding down the zinc content. In addition, stress-corrosion cracking inhibitors such as chromium are added and the artificial aging treatment is generally a compromise between maximum strength and the susceptibility to stress-corrosion cracking.

Fabricating Properties — Production of an alloy on a commercial scale requires that it be fabricated without too much difficulty so the cost will not be prohibitive. Compared to low-strength alloys, all of the high-strength aluminum alloys are much more troublesome in production. The high alloy content produces heavy segregation if water-cooled molds and special casting techniques are not employed. Piping and shrinkage cracks must be watched carefully. Ingots are generally scalped by machining all over, prior to rolling or other forging operations. Throughout the entire fabrication process, great care must be exercised and even then scrap may be relatively high compared to the more easily handled low alloys. The strengthening alloy additions have to be held down, therefore, to a point where reasonable fabricating results may be obtained regardless of some loss in mechanical properties.

Cost — The dollar sign enters the picture directly or indirectly in all of the previously mentioned factors — particularly in fabrication. With regard to a new alloy addition, the cost is direct. Rare or precious metals are ruled out entirely in a commercial product. The cost, availability, and strategic importance of even the more common elements must be considered. Only during periods of wartime production is cost relegated to a secondary consideration.

Strength — A strengthening alloy addition for aluminum must be capable of participating in the precipitation hardening process. An examination of existing alloy constitution diagrams will indicate those elements which have possibilities due to their partial solubility in hot, solid aluminum, and a solvus line which indicates a decreasing solubility as the metal cools to room temperature.

Stretch-Forming Sheet Into Aircraft Parts Is Itself a Severe Test of Quality. Photo Courtesy Westinghouse Electric Corp.

All the factors involved in the design or formulation of alloys possessing partial solubility are not known precisely, but recent work has afforded enough information to guide the metallurgist in his search. The principal factors affecting solid solution formation in aluminum are:[23]

1. "Size Factor" — Solid solutions are unlikely to form if the interatomic distance of the solute constituent differs by more than 15% of the interatomic distance of the solvent constituent. This is one of the most useful guides metallurgists have to predict possible solid solution ranges.
2. "Relative Valency Factor" — In general a metal of a given valence is more likely to form solid solutions with a metal of higher valence than one of lower valence.
3. "Electronegative Valency Factor" — This term indicates whether the alloy's components tend to form stable intermetallic compounds rather than solid solutions.
4. "Type of Space Lattice" — A geometrical factor which has a bearing on solid solution formation. Like lattices tend toward a higher degree of solution than unlike lattices.

Size factor is generally accepted as the first and most important consideration. Applying the 15% rule without regard to many other factors such as cost, specific gravity, metals with more than one interatomic distance value, and so on, we have the following metals as possibilities:

Li, Mg, Ti, V, Mn, Cr, Co, Fe, Cu, Zn, Ga, As, Zr, Cb, Mo, Ru, Rh, Pd, Sn, Ag, Cd, Sb, Te, Hf, Ta, W, Pt, Ir, Bi, Hg, Au, Os.

This list of 32 metals is drastically reduced when other factors are considered, but not all of them have been examined thoroughly.

The above theoretical factors 1 to 4 have definite limitations when used to select an alloy addition, but so also has the empirical try-and-test method or what is often called "shotgun research" where a likely field is covered at random in the hope that some useful portion will be hit. However, even with the judicious use of both approaches, the problem requires long, thorough and costly investigations.

There remains a good possibility that certain variations in the current heat treating practice for high-strength alloys may uncover additional strength. Published information on this phase of the problem has been relatively scarce. Higher strength is often attained with the Cu-Mg-Zn-Al type of alloy by reducing the artificial aging temperature, such as is recommended for Zicral. Possibly the stress-corrosion factor curtails this approach, or else the longer aging times may be uneconomical. Other possibilities might be the development of new, double aging treatments, or the use of a limited degree of strain hardening between the solution heat treatment and artificial aging in order to produce a more general precipitation.

The trend to date has apparently been to direct the heat treatment along lines that insure favorable fabrication and stress-corrosion resistance rather than to improve strength.

Conclusions

The high Cu-Mg-Zn-Al type of alloy affords the highest strength among wrought aluminum alloys we have today. It seems reasonable to expect eventually a commercial alloy with an ultimate tensile strength of 100,000 psi. to be marketed by using this general type. The production of a much stronger alloy appears some distance off, and will require extensive research.

The effect of other light alloys on the development of high-strength aluminum should not be entirely neglected. Aluminum still maintains a lead over magnesium, particularly in regard to strength, fabrication, cost and corrosion resistance. Aside from cost, beryllium or beryllium-base alloys have so far proved disappointing. Titanium, however, may prove a rival, despite its higher specific gravity, if costs can be lowered. Its strength, corrosion resistance and high temperature properties would be very attractive in some fields currently occupied by aluminum. The aircraft industry, for example, which has long been responsible for encouraging the development of high-strength aluminum alloys, may in the future have to turn to other metals for many applications where elevated temperatures are being encountered.

Aluminum and steel compete with each other for certain applications. When considering only the strength of these two constructional materials, aluminum's enthusiasts often ignore two advantages possessed by steel. In the first place, no alloying element is yet known that is anywhere near the counterpart of carbon in iron. Secondly, the heat treatment of steel has the great advantage of utilizing the allotropic nature of iron, and there seems little chance of changing the face-centered cubic structure of aluminum. Thus we must rely on the less satisfactory method of precipitation hardening.

No single alloy is a universally acceptable constructional material. The high-strength wrought aluminum alloys have their limitations but also have many outstanding and desirable properties. The eventual development of higher mechanical properties in these alloys will depend largely on the demand of the industry. The ultimate ceiling cannot safely be predicted.

(References will be found on p. 404)

The A. E. C. Reports Progress

THE SIXTH semi-annual report of the Atomic Energy Commission to the Congress (July 30) devotes 136 of its 200 pages to the Commission's activities in the fields of biology and medicine. These involve the study of the effect of radiation on human, animal and plant tissues, protection against radiation, the effect (if any) on heredity, improved methods for the irradiation of cancer, and the preparation of "tagged atoms" for a wide variety of researches, most of them on the processes of plant and animal life. (A brief appendix summarizes the National Research Council's numerous studies of Japanese exposed to atomic bombings, and a similar number of "controls" — unexposed citizens. So far, the only definite finding is that there is no significant difference in blood counts.)

Considerable space is also given to the problems of city management and to security and accounting for materials — possibly a reflection of Senator Hickenlooper's derogatory charges.

"Development and production of weapons and fissionable materials continued to be the central concern of the Commission. The new and more effective atomic weapons tested at Eniwetok in 1948 are in production. Components are being produced on an industrial basis by private concerns or special governmental facilities. All operations in the field of military application have continued to accelerate."

As to production of fissionable material: "Comprehensive examination of virtually every rock formation in this country, and of mine and smelter products, and gas and oil wells has revealed enormous tonnages of very low-grade materials which could be utilized should lower-cost uranium cease to be available. A sixth plant for ore treatment in the Colorado Plateau is being constructed; three of the six are now producing uranium, two will begin this fall.

"There have been successful pilot plant tryouts of two new processes, one for producing 'green salt' and the other for producing UF_6, which will cut costs by about 60%. Mechanical improvements and reduction of man power have cut costs of producing U^{235}; for example, in May 1949 there were 4700 employees at the K-25 separation plant in Oak Ridge (Tenn.) as compared with 11,400 early in 1947.

"New and imaginative techniques devised at Hanford (Wash.) have extended the useful life of the war-built reactors producing plutonium. Together with better operating techniques, this has brought production to an all-time high, so that $150,000,000 in contemplated new reactor construction can be deferred. As part of a $450,000,000 construction program, additional new production facilities have been brought near to completion. A new plant for processing plutonium metal is ready for operation.

"About 6500 scientists and technicians are engaged [by the Commission and more than 50 institutions] in applied research on improved processes for fissionable materials, reactors and weapons." Typical problems include extraction of uranium from ores containing a few ounces per ton, improved isotope separations, materials for constructing power reactors, sorting of materials generated by the fission process, concentration, storage or disposal of radioactive wastes, light-weight shields against radiation, and the question "Can reactors be built to produce fissionable material faster than they consume it, and if so, how?"

Reactor development is now in charge of L. R. Hafstad, formerly executive secretary of the National Defense Establishment's Research and Development Board. "A long-range development program has been approved; a major part of the work consists of development of new materials for structural purposes, for shields against radiation, and heat transfer equipment. The problems are so complex that before finally answered the present approaches may have to be abandoned entirely and new projects established. To test and operate new reactors without hazard to any large community, a large site in southern Idaho has been selected.

"Some 20% of the Commission's 4700 employees worked full time at insuring security, as well as 9% of contractors' personnel. Activities ranged from evaluating candidates for jobs and guarding shipments to accounting for materials in process and documents in some 1300 different locations in the United States."

A three-page section is headed "Research in Metals". It cites the fact that certain essential parts of power reactors should work at the highest practicable temperatures and pressures, yet "a number of creep-resistant steels particularly developed for high-temperature use contain chromium, nickel, molybdenum, or cobalt, all of which (including iron itself) absorb neutrons and are therefore undesirable. New materials must be developed." [Radiation is believed to affect the rate at which creep occurs.]

Corrosion or oxidation at high temperatures is an associated problem. "Use of liquid metal coolants, important in keeping operating temperatures within bounds and in transmitting heat from a reactor to a thermal engine, creates another serious problem of corrosion" [as well as wash from alloying and inter-diffusion].

"For the present, most of the metallurgical projects supported by the Commission [in outside laboratories] seek fundamental knowledge of metals in the solid state, such as diffusion mechanism, energy of various crystallographic lattices, the mechanism of creep, heat conductivity at high temperatures, and the relation of internal energy to mechanical properties of alloys. Present contracts concentrate much of this work in large research centers. In the future, the Commission hopes to take greater advantage of the talents of able investigators in other universities throughout the country."

Distinguished Metallurgists

Five of the 75 Recipients of A.S.M.'s Distinguished Service Award for Meritorious Contributions to Progress in Alloy Steel

Charles Frederick Pascoe

General Manager of Foundries
Canadian Car & Foundry Co., Ltd.
Montreal

Citation "for improvement and development of alloy cast steels for general engineering use in Canada"

BORN in South Wales, educated at Swansea and London, chemist in Llanelly Steel Works (South Wales) and Zavord Gougon Works (Moscow), metallurgist and executive with Canadian Car & Foundry Co. since 1911. Behind these data on the career of C. F. PASCOE is a long experience in foundry metallurgy and technology.

Describing specific developments in alloy steel castings, PASCOE says, "Six-bladed impeller-type turbine castings weighing 80,000 lb. were exceedingly difficult to heat treat without excessive distortion of the curved blades. I demonstrated to the power company that all their specifications could be met without heat treatment by slowly cooled low-carbon nickel steel castings. We have made many such castings over a 20-year period and never once had a failure.

"In conjunction with W. A. Newman of the Canadian Pacific Railway Co., we made extensive experiments with full-size locomotive main sideframes using nickel, nickel-vanadium, vanadium, molybdenum, manganese-vanadium and manganese-molybdenum steels. The full-size castings were heat treated and cut up for all the physical and chemical tests we could apply, particularly in regard to the relation of attached test coupon to full-size section of the castings. Papers were published on the subject and the ultimate result was that low-carbon nickel steel became standard on the Canadian railroads, with much better physical properties specified than for carbon steel."

Similar details might be cited concerning development work on alloy steel rolls for hot and cold rolling mills, manganese-nickel steel for railroad crossings, and many other alloy steel castings for engineering use.

All these new alloys have contributed greatly to the steady industrial development of Canada that has taken place during the 38 years since C. F. PASCOE became a metallurgist for Canadian Car & Foundry.

Edgar C. Bain

Vice-President
Carnegie-Illinois Steel Corp.

Citation: "Investigator, author, adviser, administrator, in many phases of alloy steel development"

FROM a metallurgical career that started with a study of lamp and vacuum tube filaments and of solid solutions by X-ray methods (General Electric Co. in 1919) and progressed through work on tool-steels at Atlas Steel Co., on chromium and on nickel-chromium steels at Union Carbide & Carbon Research Laboratories, and on the engineering alloy steels at United States Steel's research laboratories, finally to vice-president in charge of research and technology for Carnegie-Illinois, the world's largest maker of steels of all sorts, the committee on awards for meritorious contributions to progress in alloy steel had no difficulty in finding numerous reasons for placing the name of EDGAR COLLINS BAIN high on the list. Some of his very earliest work with X-rays clarified for the American metallurgical fraternity two fundamental aspects of the hardening of steels (especially alloy steels) in that it established a clear picture of the atomic architecture or space lattice of solid solutions, and the changes in the lattice of the soft solid solution of carbon in gamma iron (austenite) to the hard, badly distorted, quasi solid solution of carbon in alpha iron (martensite).

Such a clarification of the

fundamentals of the hardening mechanism was but a forerunner to the work he initiated in the late 1920's at U. S. Steel's Kearny laboratories on the changes in hot austenite when it is suddenly quenched to certain elevated temperatures and held there continuously, and how these changes are slowed down or altered by the alloy in the steel. These studies produced the now well-known and highly useful "isothermal transformation diagrams", clarified several obscure happenings during the quenching process, developed an entirely new philosophy of the annealing processes and the "austempering" heat treatment, and isolated a new microconstituent now called bainite in his honor.

Since the ⊜ awards were given primarily to people who *started* things, it might have been sufficient to rest the citation on one thing alone — his systematic analysis of the "Functions of the Alloying Elements in Steel", a publication which contains the first comprehensive and quantitative appraisal of the whole field. Its preface states it was aimed "to make an admittedly complex technical subject seem convincingly simple". It can truly be added that the book is rather the manifestation of orderly thought about an extraordinarily wide range of facts, and clear writing—in short, good teaching. It is the starting point for innumerable improvements in alloy steel, already made or yet to be made.

Adolph O. Schaefer

Assistant to Executive Vice-President
The Midvale Co.
Philadelphia

Citation "for development of many special alloy steels for use in ordnance and the heavy industries"

IMMEDIATELY after graduation from the University of Pennsylvania, ADOLPH SCHAEFER joined Midvale Steel and Ordnance Co. (now The Midvale Co.) as a research assistant. Today, 27 years and six promotions later, he is in charge of the company's diverse technical activities.

In the Midvale tradition, AD SCHAEFER has had a long and continuing interest in steel forgings — chiefly large, very large, and enormous. Take rotors, for example: When SCHAEFER first came to Midvale, turbine and generator rotors were being made of either carbon steel or nickel steel. Evolution has brought into general use today's nickel-molybdenum steels, which usually contain a small amount of vanadium. This may seem like a small change; but when forgings of 10 to 100 tons are being considered, any change in alloy content is a major decision, to be made only after careful deliberation.

The evolution in large alloy steel forgings has its record in the documents of the technical committees that have worked out the pertinent specifications. In fact, the industrial history of alloy steels might be written from the records of such technical committees. Compiled in that way, history would give a prominent place to ADOLPH SCHAEFER, for he has served with distinction on the committees of the American Society for Testing Materials, American Society of Mechanical Engineers, American Iron and Steel Institute, Forging Manufacturers' Association, and Locomotive Tire Manufacturers' Association.

SCHAEFER's recognized ability in the metallurgy of alloy steel and his record of service in the various societies and associations made it fairly inevitable that he should have an important place in the wartime technology of large-caliber gun tubes. Besides being a member of the Joint Metallurgical Committee of Great Britain and the United States, he was chairman or industry leader of two American committees that correlated technical information on forged gun barrels made of alloy steel. The success of this work is proved by the satisfactory way in which production schedules were met in the 38 different plants making these guns, in spite of the limited supply of alloying elements.

Ernest E. Thum

Editor, Metal Progress
Cleveland

Citation "for gathering, interpreting and presenting information about alloy steels in all their aspects"

BACK IN 1908 a young man of 24 with the title of chief civil engineer had the exhilarating experience of supervising all field engineering for a railroad and copper smelter at Tooele, Utah. A mining engineer graduate of Colorado School of Mines, this enterprising youngster could hardly foresee that 40 years later he would be awarded a distinguished service citation for work in the field of alloy steels.

The road from field engineer to editor, from copper smelting to top-flight publicist was a fairly direct one, despite the discrepancy in the scenery at either end.

The first and sharpest bend in the road came with the outbreak of World War I, which shut down Anaconda Copper Mining Co.'s Great Falls smelter, where ERNEST THUM had been transferred as chief engineer after the completion of the Tooele plant. Taking a deep breath, he forsook his beloved western mountains and moved eastward to University of Cincinnati as professor of metallurgy. Here for two years it was a case of the "professor studying like mad to keep one jump ahead of his classes".

The next turn had been foreshadowed by an earlier event, when a contribution to the magazine *Metallurgical and Chemical Engineering* had brought a check for $50 to the young professor. The editor had not forgotten the talent for succinct technical writing exhibited in this first contribution, and when an opening developed on the staff of *"Met and Chem"*, ERNEST THUM got the job, and for six years he devoted himself to developing information on advanced metallurgical processes wherever he might find them.

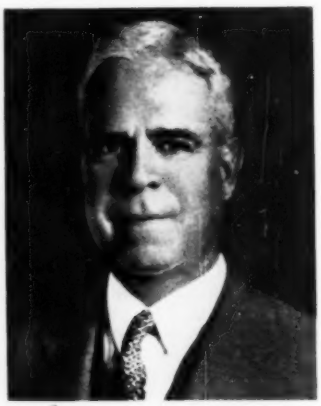
Then, in 1923, McGraw-Hill decided that chemistry and metallurgy did not mix, and that chemistry had the brightest future for a monthly magazine. The metallurgical editor, out of a job, then took a brief detour on the other side of the publishing fence by organizing the technical publicity department for Union Carbide and Carbon Corp. Three years later he was back on the editorial highway on the staff of *Iron Age*, and in 1930 came the turning that climaxed his professional career.

Here *Metal Progress* loomed on the horizon, envisaged by its originators among the trustees of the American Society for Metals as a publication that would establish new records for quality in the field of technical publishing. ERNEST THUM, its editor, brought to fruition the dreams of its originators.

Not only has he constantly sought and published good new information on alloy steel for this monthly magazine. In the book field he produced the wartime indispensable "NE Steels", and the textbook "Modern Steels". As an author in his own right, his list of contributions to alloy steel development is imposing and includes such notable items as the leading articles for the Encyclopedia Britannica, War Metallurgy Committee's reports on strategic metals, and an early investigation of the then newly developed medium manganese steels.

Perhaps the best examples of Editor THUM's ability to translate technical developments into brief, understandable, pithy prose are contained in his editorial column entitled "Critical Points". His own function — and that of *Metal Progress* — may well be expressed in a quotation from a Critical Point concerning the silver anniversary of Standard Oil's development laboratory: "Over and over it was emphasized that research would be barren, commercially, if its results were not understandably interpreted to the operating and production management."

M.R.H.



Albert Easton White

Director
Engineering Research Institute
University of Michigan

Citation "for contributions in the development, promotion and selection of steels for high-temperature service in power plants"

WHEN Lt-Col. A. E. WHITE, U.S.A., resigned his commission after World War I, he rejoined the chemical engineering faculty at Ann Arbor. His army service as head of the metallurgical branch of the ordnance department's technical staff had brought him in contact with many progressive business men, and he had found them unfamiliar with metallic alloys and treatments used for war materiel, yet anxious to appraise their utility to peace-time activities. He was convinced that a great state university should provide means whereby such matters could be studied, and he was selected by the University regents to establish the Department of Engineering Research, where industrial problems could be studied by a staff whose resources would include the entire engineering faculty and laboratories of the University. This idea was bold, for its day; its success is proved by the many institutions which have followed suit.

One of the first firms to enter into such a research contract was the Detroit Edison Co., which previously had retained Professor WHITE as consultant. In 1925, C. L. CLARK was employed as full-time investigator of high-temperature properties of metals. It was practically a new field. Much time was required to refine the testing equipment so materials could be held under load at high temperatures without variations for years on end, and the stretch measured periodically to a few millionths of an inch. Eventually (1938) the "stress-rupture" test was proposed by CLARK and WHITE, and has since been widely accepted by designers of equipment for many high-temperature processes as a means of measuring anticipated performance.

It was natural that Timken Roller Bearing Co. should come to Ann Arbor as a center of information when, in 1929, it desired to promote seamless tubing in the power and petroleum fields. Under ALBERT WHITE's direction the chromium-molybdenum steels for high-temperature service were developed. For similar reasons the power industry generally looks to Prof. ALBERT EASTON WHITE for advice. Without his 30 years of study of high-temperature steels, the modern central station, ever more efficient by virtue of higher temperatures and higher steam pressures, might not be in existence.

By W. E. Kingston
Manager, Metallurgical Research
Sylvania Electric Products, Inc.
Bayside, N. Y.

Planning of Engineering Research

DURING the past decade, an ever-increasing number of industries have utilized engineering research and have found it to pay good dividends. The radio tube and incandescent lamp companies have long supported extensive research activities; in fact, research has become a prerequisite of survival in these highly competitive industries. With this experience in basic and applied research has come the opportunity to study and evaluate various methods of engineering planning.

Engineering planning can be applied in several ways, two of which are of prime importance: first, budget control of engineering expenditures, and second, the planning of research from the standpoint of optimum technical return from engineering man power.

Budgets can usually be controlled by well-known accounting principles. In this article, we shall concentrate on the second, or engineering efficiency, phase of research. Our object will be to outline one method of planning basic and applied research that has made available improved returns from engineering effort, not only in terms of practical and theoretical results, but also from the standpoint of the satisfaction and happiness of engineering staff members.

One of the "bugaboos" confronting an organization which wishes to embark on a research program or one which tries to improve research efficiency is the prevalent idea that to *organize* research is to destroy initiative and otherwise to cramp the style of the participating engineers. Although this line of thought is quite general, even in research organizations, nothing could be further from the truth, provided the method of planning or organization is properly thought out and applied. It is sometimes suggested that, although it may be possible to plan engineering development work effectively, it is impractical to do so for studies of a more basic nature. This obviously is an overstatement.

The philosophy of planning which we have utilized to good advantage in our metallurgical research and development division is in reality a method of organization of engineering thinking in terms of long-range and short-range objectives. This may seem a trite and obvious statement, but a great deal of engineering research appears to be conducted with little more than lip service to the above principles.

In order to make the following discussion more specific, I shall refer to our own scientific group, on which we have concentrated this type of engineering planning. The group comprises some forty scientists plus laboratory technicians and clerical personnel. Of the scientists about 30% have doctorates, 30% master's and the rest bachelor's degrees. Four section heads (responsible for basic research, applied research, physical metallurgy, and advanced development) and the service foreman report to the manager of metallurgical research.

In organizing our engineering projects we emphasize the basic principle that it is necessary to determine the objectives clearly, and having established these, to plan the program accordingly, bringing in at the appropriate time those persons who are qualified to make pertinent contributions. Such long-range planning becomes difficult at times, due to the changing nature of a specific project as a result of unanticipated technical findings. Therefore, a shorter range planning should supplement the longer range. But the ultimate objectives should always be kept in view.

This engineering planning is a method of objective thinking and requires an appreciation and participation by all personnel involved. It does put a premium on management and super-

PROJECT REVIEW

TITLE: Kinetics and Catalysis of Tungstic Oxide Reduction — PROJECT No. 186 — DATE 8/4/49

ASSIGNED TO: D. R. Lewis — BY: S. N. White, Head Applied Research Section

DURATION: 6 months

PERSONNEL REQUIREMENT: 400 engineer-hours and 200 technician-hours

EQUIPMENT: One reduction-rate furnace with accessory equipment to be designed and constructed in laboratory. Cost, $1500.

SERVICES: Particle size analyses, X-ray analyses, metallographic analyses.

OBJECTIVES:

1. To increase our understanding of the nature of the reduction process.
2. To determine more quantitatively the effect of hydrogen flow on particle size and distribution.

(Other objectives listed.)

REQUIREMENTS:

1. To improve the quality of tungsten powder.
2. To reduce costs of manufacture by establishing improved processing techniques and engineering controls.

(Other requirements listed.)

DISCUSSION: (Should be presented comprehensively.)

Since the process used in reducing WO_3 to tungsten metal consumes considerable time, labor and equipment, it is felt that a study of the reaction may reveal steps that can be taken to reduce this expenditure and also bring about better quality and engineering control of the tungsten powder produced.

Among the unanswered problems are:

1. In the reaction $3H_2 + WO_3$ to $3H_2O + W$, we would like to find what intermediate reactions occur and at what rate each reaction proceeds under various conditions of temperature, hydrogen flow, etc.

(Other pertinent problems listed.)

PROGRAM:

A. Determine the effect on the rate of reduction of hydrogen flow, temperature, depth of WO_3 powder, water vapor, and various catalysts.

B. Correlate the rates of reduction with particle size, particle size distribution, degree of sintering, structure of particles, and density of powder.

C. Study these results with a view to improving the present reduction process.

Approval By W E Kingston Manager, Metallurgical Laboratories

visory personnel who can "see the trees from the woods" and plan and direct research activities accordingly.

If carried out entirely by discussions, the objective planning often fails to accomplish optimum results because, over a period of time, most personnel cannot remember exact details of the original plan. Thus there may be a tendency, especially among those lacking wide experience, to divert from the original objective. Therefore, we prefer to supplement our long and short-time thinking by certain recorded forms which, for want of better terms, we call Project Reviews and Work Outlines. It cannot be overemphasized that these forms are only the reporting of planned thinking, in which all of the engineering personnel involved in a specific project should participate.

Which Projects Should Be Reported?

Naturally, it is not feasible to report on all projects. Many projects are of short duration, some are purely routine, and some are entirely preliminary; all these may be considered as minor projects. Although it is impossible to specify exactly which types of project should be reported, we can lay down some general rules on what constitutes a major or reportable project:

1. Any project (except routine analyses) which is estimated to require more than 20% of an engineer's effort over a period of three months or more, is a major project.
2. Any project of critical importance should be considered a major project.
3. Minor projects can become major if results indicate that their value is great enough to justify appreciable engineering time.

All other projects are to be considered minor ones and do not require Work Outlines or Project Reviews. It should be noted that this system of planning is not a substitute for formal reports on work either in progress or completed.

The Project Review

The project review is our method of recording long-term general thinking on major projects. Once it has been decided that a new engineering project should be initiated, a project review is made out by the appropriate section head before the actual work begins. The project review should be comprehensive, but as brief as is consistent with a clear presentation of the subject. The specimen shown as an insert on this page will indicate the form we use. The details would, of course, vary greatly, depending on the particular project.

After the project review has been approved by the manager of the division, copies are given to the section heads and participating engineers. Work on the project is then initiated.

The Work Outline

The work outline, shown on the next page, is a method of recording the short-term, specific planning on major projects over a given work period. It is also used to report performance during the work period, and thus allows a comparison of planned and accomplished work over the period of the project. It should be prepared by the section head as a result of discussions with the engineers involved, preferably at the time of routine project discussion. The ideas and participation of the engineers should be encouraged.

The long-term objectives should be kept in mind, but short-term planning may logically set up intermediate objectives consistent with the principal goals. The objectives may be changed during the work period because of unanticipated results from tests in progress. Such changes should be explained in the subsequent work outline.

The work period may vary in different projects. Thus, a basic research which is planned

over several years may be reported on over periods not to exceed three months. On projects of an advanced development nature, the work period should not exceed six weeks. In our experience, a work period of two months has usually been adequate. The exact date of reporting is not critical, but reports should be reasonably punctual. Some latitude is desirable where results of special significance are to be expected a few days after the end of the normal work period.

When no work or little work has been carried out, or when results fall below expectations, these facts should be reported. It is equally important to know why work has *not* been carried out, and also when results do *not* come up to standard, in order that corrective steps may be taken. Frequently the fact that results are inadequate is due to lack of facilities, diversion of engineering efforts to other projects, or other matters which should be considered against the importance or value of the respective projects.

Advantages

Planned research has these advantages:

1. It gives the individual engineer a clear idea of the direction of his efforts, as well as an outline of specific tasks to be accomplished.

2. It gives the engineer the satisfaction of accomplishing clearly defined objectives.

3. It allows the development of a project along logical directions, with proper emphasis on pertinent lines of attack, thus minimizing shotgun methods and improper emphasis on minor details.

4. It gives the individual engineer, as well as the section head and manager, a method of evaluating results over a given period against corresponding objectives.

5. It gives the section head a method of planning and controlling the work in his group, which will allow him to function most effectively. It should make necessary a minimum of day-by-day spot planning, and thus make available a greater portion of his time for additional work.

6. It gives the section heads and manager a composite picture of the various activities in their sections, thus affording a means of evaluating distribution of man power, costs and technical progress.

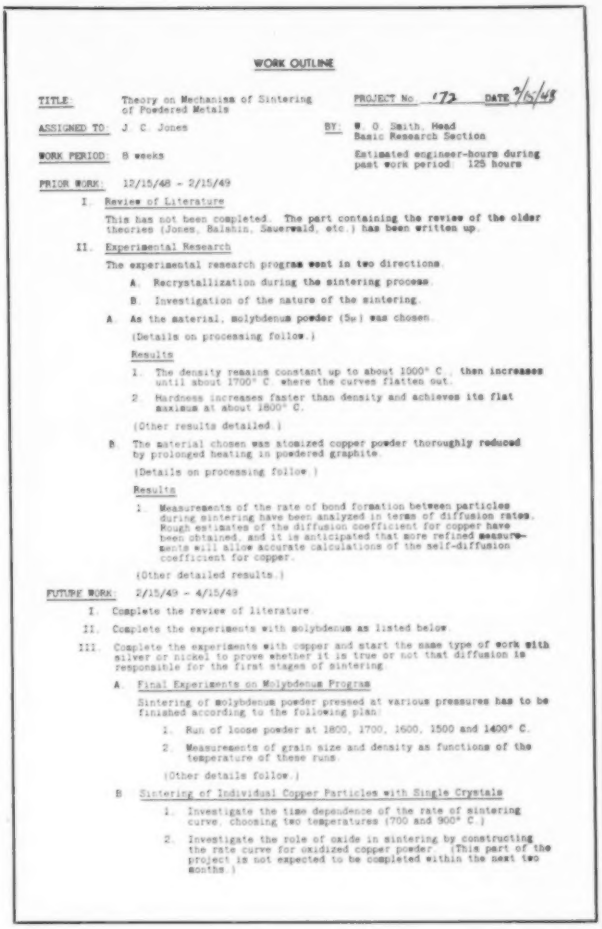
7. It allows the manager to concentrate his direction on projects which require emphasis.

8. It predicates the setting up of a goal to be reached in a given time. This, in the writer's experience, is an absolute necessity for maximum efficiency of engineering effort.

9. Such a method will assist the manager to keep in close touch with the work of his division, without an excessive amount of personal contact.

10. It gives greater return per engineer-hour.

11. It encourages long-range thinking of engineers, thus developing supervisory personnel.



WORK OUTLINE

TITLE: Theory on Mechanism of Sintering of Powdered Metals — PROJECT No. 172 — DATE 2/15/49

ASSIGNED TO: J. C. Jones — BY: W. O. Smith, Head, Basic Research Section

WORK PERIOD: 8 weeks — Estimated engineer-hours during past work period: 125 hours

PRIOR WORK: 12/15/48 - 2/15/49

I. Review of Literature

This has not been completed. The part containing the review of the older theories (Jones, Balshin, Sauerwald, etc.) has been written up.

II. Experimental Research

The experimental research program went in two directions.

A. Recrystallization during the sintering process.

B. Investigation of the nature of the sintering.

A. As the material, molybdenum powder (Sw) was chosen.

(Details on processing follow.)

Results

1. The density remains constant up to about 1000° C., then increases until about 1700° C. where the curves flatten out.

2. Hardness increases faster than density and achieves its flat maximum at about 1600° C.

(Other results detailed.)

B. The material chosen was atomized copper powder thoroughly reduced by prolonged heating in powdered graphite.

(Details on processing follow.)

Results

1. Measurements of the rate of bond formation between particles during sintering have been analyzed in terms of diffusion rates. Rough estimates of the diffusion coefficient for copper have been obtained, and it is anticipated that more refined measurements will allow accurate calculations of the self-diffusion coefficient for copper.

(Other detailed results.)

FUTURE WORK: 2/15/49 - 4/15/49

I. Complete the review of literature.

II. Complete the experiments with molybdenum as listed below.

III. Complete the experiments with copper and start the same type of work with silver or nickel to prove whether it is true or not that diffusion is responsible for the first stages of sintering.

A. Final Experiments on Molybdenum Program

Sintering of molybdenum powder pressed at various pressures has to be finished according to the following plan:

1. Run of loose powder at 1800, 1700, 1600, 1500 and 1400° C.

2. Measurements of grain size and density as functions of the temperature of these runs.

(Other details follow.)

B. Sintering of Individual Copper Particles with Single Crystals

1. Investigate the time dependence of the rate of sintering curve, choosing two temperatures (700 and 900° C.)

2. Investigate the role of oxide in sintering by constructing the rate curve for oxidized copper powder. (This part of the project is not expected to be completed within the next two months.)

It is impractical to set forth fixed rules on such a program, in view of the diversity of engineering research and development work, as well as variation in personality and types of personnel. Any program of planned research must be flexible enough to allow adequate opportunity for individual incentive in following up new ideas, but in the main it should keep the over-all scope of a project within the desired range and direction. For the more basic or fundamental work, it may be difficult to be as specific in planning as for work of an advanced development nature. Nevertheless, specific planning toward definite objectives should be done as far as possible. Such organization of research requires a conscientious initial effort from all concerned, but as the details are improved, the system functions smoothly. In its present stage of development our own method is definitely a timesaver, and a real increase in efficiency has resulted from its use.

Occupational Analysis of the Metallurgical Profession

Report of a Survey by ⊜ Advisory Committee on Metallurgical Education

Alexander R. Troiano, Chairman

THE American Society for Metal's Advisory Committee on Metallurgical Education has recently completed an occupational analysis of the metallurgical profession. It is believed that such a study had never been made; other studies — as the recent one on the engineering profession and mentioned last month (p. 258) made by the U. S. Department of Labor — do not distinguish between metallurgists and mining engineers (on the one hand) and between metallurgical engineers and mechanical engineers. Thus it has not only been difficult to evaluate the activities of metallurgists and metallurgical engineers but also to define metallurgical engineering itself.

Because of the bearing of such an analysis upon any effort to define what industry and society desire in metallurgical graduates or engineers engaged in metallurgical work, the survey should obviously be made under the auspices of such a national organization as the American Society for Metals. The present writer is the chairman of the ⊜ Advisory Committee on Metallurgical Education which made this survey. Other members are: Alfred Bornemann, John Chipman, H. P. Croft, J. L. Gregg, M. A. Grossmann, M. A. Hunter, R. F. Mehl, L. M. Pidgeon and John W. W. Sullivan.

Walter Morrison of the society's staff performed the tedious work of analyzing the data. The results which are susceptible of tabulation are presented herewith, without interpretive comment.

To make this analysis, 3000 questionnaires were sent to names selected at random from the

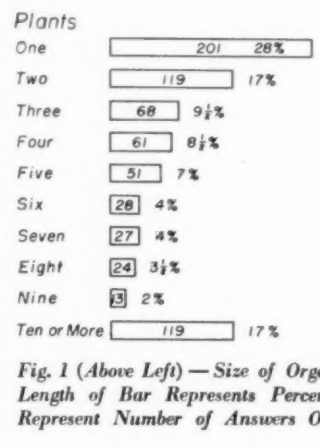


Fig. 1 (Above Left) — Size of Organizations Employing Metallurgists; Length of Bar Represents Percentage of Those Reporting; Figures Represent Number of Answers Out of 916 Questionnaires Returned

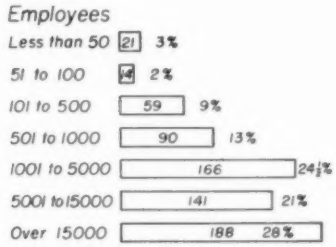


Fig. 2 — Size of Organizations Employing Metallurgists as Measured by Number on the Payroll

roster of ASM members about whom the available data (required by Audit Bureau of Circulation to certify the accuracy of *Metal Progress*' circulation analysis) indicated that they are actively engaged in metallurgical pursuits. Unless noted otherwise, all the data presented herewith are based upon 916 questionnaires returned.

The size and method of selecting the sample from among the 20,800 members of the ASM was adopted after careful consideration, so that the 3000 names on the original list represented a composite of the metallurgical profession — the "median metallurgist", if such a being can be imagined. About one third of the questionnaires were returned — quite a high percentage, we are told by professional pollsters. The results were analyzed from time to time as the questionnaires were returned. It is significant, as to final accuracy, that no essential variations in the trend of the results were noted after approximately 450 returns were received and analyzed.

Line of Manufacture

To the query as to the principal product of the organization with which the respondent is connected, not all answered. Tabulation of the available data is as follows:

Product	
Manufacturer of assembled parts	299
Commercial processing	358
Other parts, not final products for sale to ultimate consumers	2
Railroads, public service, nonmetals	12
Producers of basic metals	201
Federal, state, municipal	
Distributors, dealers	5
Consulting and contracting	14
Trade associations, Chambers of Commerce, libraries, schools	
Students	
Armed forces	
Total	891

Work Categories

The first part of the questionnaire constituted an attempt to analyze the categories of work in which members are engaged. As a guide to answering this section of the questionnaire, the explanation and illustration of work categories noted in the tabulation at the right of this page was included, together with the totals responding. A few (15) divided their time between two classes of work. (Not all questionnaires were fully answered, hence the figures derived do not add to 916 in all instances. Percentages are usually computed on the total of those who did answer the query under consideration.)

Work Categories, by Groups

	Number	Percentage*
A. **Metal Production** — Employed in any capacity by a company involved in the winning, refining or shaping of metals, whose products are metals for the use of other industries.	331	36
B. **Metal Consumption** — Employed in any capacity by a company purchasing, fabricating and consuming metal.	523	57
C. **Education** — Employed in any capacity by a university, college or secondary school.	—	
D. **Nonprofit Institution** — Employed in any capacity by a private nonprofit research institution.	5	<1
E. **Government** — Employed in any capacity by state or local governments, the government of the United States, of another country or an organization of countries.	9	1
F. **Technical Society** — Employed in any capacity by a technical society.	1	—
G. **Publishing House** — Employed in any capacity by an organization publishing or selling books or periodicals.	—	
H. **Commercial Service Co.** — Employed in any capacity by an organization providing services to industry for profit; consultant, attorney, commercial heat treat shop, independent laboratory.	47	5
Total	916	

Class of Work

1.	**Technical Production Problems.**	405	44
2.	**Technical Research or Development.**	324	35
3.	**Sales** — Questions of price and delivery are paramount.	24	3
4.	**Technical Contacts With Customer** — Question of quality is paramount.	79	9
5.	**Purchasing** — Questions of price and delivery are paramount.	—	
6.	**Technical Contacts With Supplier** — Question of quality is paramount.	22	2
7.	**Management** — Supervision of men is primary responsibility.	74	7
8.	**Personnel** (primary responsibility)	—	
9.	**Finance.**	1	
10.	**Teaching.**	1	
11.	**Editing or Writing.**	—	
12.	**Legal.**	1	
Total		931†	

*Percentage figured on 916 in both.
†Some entered more than one class.

Titles

Director of Research	32
Chief Metallurgist	120
Metallurgist	510
Engineer (Materials)	73
Engineer (Production)	47
Superintendent	26
Supervisor	56
Foremen	7
Sales	30
Officials	14
Owner	1
Total	916

Table I — Income of Metallurgists, Depending on Responsibility

Principal Responsibility	Number Reporting	Highest Income	Lowest Income	Median Income	Average Income
Administration	42	$20,000	$3,600	$9,875	$10,528
Sales	26	24,000	3,600	7,200	7,356
Metallurgical control	136	18,000	3,800	7,000	7,221
Supervisory	66	15,000	3,600	6,950	7,027
Research	120	35,000	2,500	6,100	6,851
Quality control	111	25,000	3,600	6,275	6,812
Production control	136	15,000	3,300	5,925	6,106
Customer service	44	12,000	3,600	5,225	5,741
Foundry and smelting	22	11,000	3,600	5,675	5,525
Heat treating	41	8,400	2,500	5,275	5,326
Technical control	82	15,000	3,000	5,725	5,322
Laboratory and testing	52	11,000	2,600	5,225	5,095
Total or average	878	16,975	3,275	(Note)	6,567

Note: Median income of all metallurgists reporting is $6368.

One question asked was designed to determine the number of plants and the approximate number of employees in the organization with which the individual is associated. Not all the returned questionnaires contained the requested information; 711 metallurgists reported the number of plants or factories in their organizations; 679 reported the total employees. Results are shown in the bar charts, Fig. 1 and 2, p. 344.

It is common knowledge that engineering titles are frequently misleading, and at best tell little of the actual duties of the holder thereof. Your guess is as good as mine as to whether John Smith, third vice-president of Transamerica Bank, has charge of rentals of foreclosed buildings, or whether Fred Jones, engineer in charge of department A, of Plant 3, of World-Wide Equipment Corp., is an expert on electroplating. Our questionnaire attempted not only to determine the titles used, but (far more important) the responsibilities and, if possible, the salary and years of experience that led to the present position. Response to the latter questions was particularly gratifying (see Table I, above). Titles are listed alongside the table.

Incomes of Metallurgists

Incomes received at present for all men who graduated in a certain year were averaged and the results are plotted in Fig. 3. Whether the peak of earning capacity is actually reached 25 to 30 years after graduation at age 45 to 55 (on the average) cannot be assured from our meager data, but the curve at any rate is in agreement with common observation.

Ranges for the various periods might have been plotted, but would have no statistical value. A good man, fortunate enough to be in a place where he can capitalize on his ability, will always have an enviable income. Our results have been recapitulated in groups as to size and are presented in Table II, which includes, for comparison, figures taken from a preliminary report on results of a survey of the U. S. college graduate population (not necessarily technical) completed by *Time Magazine* in 1948, approximately one year prior to the completion of our survey, as well as figures about the entire population of the

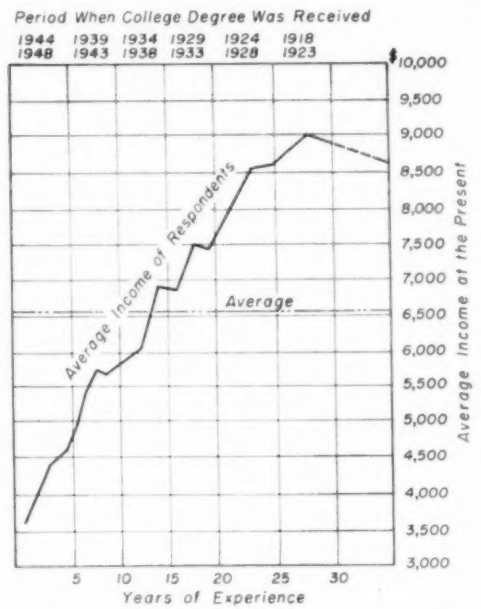


Fig. 3 — Average Income According to Period of Employment Since Receiving College Degree. The median income of all metallurgists reporting is $6368

Table II — Classification According to Income Levels

⊖ Survey of Metallurgists*		Time Survey of College Graduates,† Per Cent	Federal Reserve Report on Population
Income	Per Cent		
Under $3000	0.76	14.4	53
$3000 to $3999	6.08	23.2	20
4000 to 4999	17.59	18.0	12
5000 to 5999	22.90	21.4	10
6000 to 6999	18.78		
7000 to 7999	11.29 ‡		
8000 to 8999	6.90	9.6	5
9000 to 9999	4.39		
Over $10,000	11.31	13.4	
Median	$6368	$4689	$2840

*Based on 921 respondents. †4748 returns (men).
‡*Time* and Federal Reserve's study subdivided the groups at $7500.

United States, taken from a Federal Reserve survey of general consumer finances, completed in 1948 and reported in the July 1949 issue of *Federal Reserve Bulletin*.*

The latter part of the ⊖ questionnaire dealt with the individual's responsibilities and distribution of his time. As an aid in answering this section, the document included the following instructions:

"Individuals in the 'line' are concerned with the carrying through of established practices, while 'staff' provides information which is used to establish or modify these practices."

The answers are tabulated as follows:

I would classify myself as a member of the

Staff	496
Line	79
Both line and staff	341

With respect to my job, I am responsible for

My own activities only	229
The activities of fewer than 10	377
The activities of 11 to 50	199
The activities of 51 to 100	44
The activities of 101 to 200	35
The activities of 201 to 400	14
The activities of 401 to 800	8
The activities of over 800	10

An interesting compilation, Table III, resulted from replies as to distribution of time. *All* 916 respondents said they spent *some* time on technical problems.

The last question was designed to find the division of each individual's time to accomplish his responsibilities. The questionnaire instructed each one to show the percentage for only the six items in the following list which required the greatest part of his time, and asked him to omit items requiring less than 2 hr. per week, 10 hr. per month, or two weeks per year. Taking as an example the first line, the numbers and percentages are to be read thus: "Of the 916 respondents, 336 did actual work in the laboratory, and these 336 spent 29.04% of their time (on the average) in laboratory work." ⊖

Distribution of Time

	Number Reporting	Average Time
Actual work in the laboratory	336	29.04%
Actual work in production	394	37.20
Inspection of products	201	14.00
Study	197	9.07
Filling out routine forms	84	12.70
Writing research or development reports or articles	220	14.17
Preparing recommendations based on routine or research reports	342	9.62
Originating and assigning research projects	216	14.00
Conferring with company associates	588	21.37
Conferring with customers or suppliers	391	17.20
Participating in technical society activities	70	6.65
Attending technical society meetings	66	7.07
Making inspection trips through own plants	238	21.04
Making inspection trips through other plants	60	8.09
Other activities	72	3.22

Table III — Distribution of Time by Activities

Proportion of Time	Technical	Personnel	Finance	Legal
100%	317			
90	287			
80	102			
75	91	7		
60	40			
50	54	37	2	
30	13	23	8	
25	11	156	31	9
10		256	75	10
<10	1	66	97	88
Totals	916	545	213	107

*Editor's Note — On August 28 the U. S. Department of Commerce announced that the median net income (representing the income below which and above which half of all the recipients lie) of 140,000 lawyers engaged in independent practice is $5719. "Net income" is defined as gross income minus costs of practice.

The Department of Labor's survey of the engineering profession (*Metal Progress*, August 1949, p. 258) gave median salaries of "mining and metallurgical engineers" as $5004, and of "chemical engineers" as $4320.

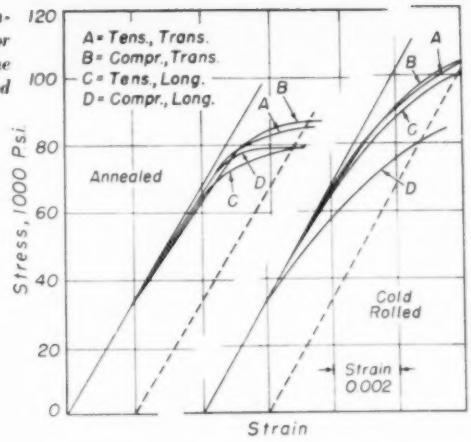


Fig. 1 — Typical Tensile and Compressive Stress-Strain Curves for Titanium Sheet From Two Heats, One Annealed (left), the Other Cold Rolled

Some New Data on the Properties of Wrought Titanium

By F. B. Fuller
Air Materiel Command
Wright-Patterson Air Force Base
Dayton, Ohio

THE nine articles on titanium in *Metal Progress* for March included considerable information about mechanical properties. Data that have become available since those articles were prepared show some peculiarities in the tensile stress-strain characteristics of titanium and extend our knowledge of fatigue and low-temperature properties. These new data, presented here, were obtained from tests on titanium sheet and bar stock furnished by the Remington Arms Co., Inc., essentially the same material discussed by C. I. Bradford, J. P. Catlin and E. L. Wemple, on p. 348 of the March issue.

The typical stress-strain curves in Fig. 1 are similar to those for aircraft structural metals.* However, stress-strain curves for repeated loading and unloading (Fig. 2) show a different hysteresis behavior. For each cycle of loading and unloading to the same stress (90% of the yield stress, which is the stress used by the Materials Laboratory in stress-corrosion tests), considerable additional permanent set occurs. Furthermore, during unloading in the region of the peak stress, the titanium sheet continues to stretch until a load equivalent to about 70% of the yield stress is reached; only then does the material begin to recover deformation.

Figure 3 shows comparable data for soft aluminum (2S-O), which has stress-strain characteristics typical of the metals that are being used in aircraft structures at present. The reader may note that, for 2S-O aluminum, repeated cycles to the same stress produce no additional permanent set after the initial set and, in the region of peak stress, the metal starts to recover deformation as soon as the load begins to decrease. Also, the amount of permanent set at the end of the initial unloading is virtually the same as the offset or plastic deformation at the top of the curve for initial loading, whereas for titanium the permanent set is greater than the offset, because of the increase in deformation during unloading.

*The typical stress-strain curves in Fig. 1 do not indicate anything unusual or different from those for aircraft structural metallic materials, such as steels, aluminum alloys and magnesium alloys. They are normal in general characteristics in that there is an initial straight line portion (modulus of elasticity slope) and a gradual deviation and curvature from the modulus line into the plastic range. Thus there is a yield strength value but no "yield point".

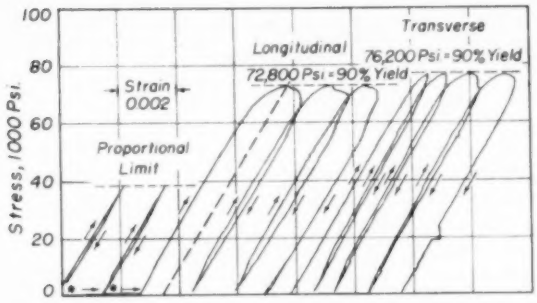


Fig. 2 — Typical Autographic Stress-Strain Curves for Annealed Titanium Sheet. For tensile properties, see Table I. At points indicated by asterisks, the drum was rotated manually so that the stress-strain curves could be observed more readily. Dashed line parallel to the modulus line indicates path of the unloading curve for a normal aircraft structural metal

Table I — Tensile Properties of Titanium Sheet

Condition	Direction of Rolling	Yield Strength (0.2% Offset)	Tensile Strength	Elongation in 2 In.
Annealed	Longitudinal	79,000 psi.	97,000 psi.	21%
Annealed	Transverse	85,000	95,000	23
Cold rolled	Longitudinal	100,000	117,000	11
Cold rolled	Transverse	104,000	119,000	18

Because of the marked difference in hysteresis characteristics of stress-strain curves for titanium (close-packed hexagonal crystal structure) and commercially pure 2S-O aluminum (face-centered cubic), it was believed that similar data on commercially pure magnesium (close-packed hexagonal) would be of interest. A few exploratory tensile hysteresis curves repeated to 90% of the yield strength (about 14,000 psi.) indicated that magnesium differs from titanium in that, during the early part of unloading, the magnesium shows no change in deformation at first but ultimately starts to recover deformation, producing a permanent set approximately equal to the offset. For each repeated loading the magnesium develops additional permanent set.

The deformation phenomenon observed for annealed titanium (Fig. 2) was noted also for cold rolled titanium, but the effect was not so great. At a higher stress — probably the yield stress — it may be more pronounced. It will be noted also that for stress in the longitudinal direction the hysteresis loop decreases in width with repeated stressing, but for transverse stressing the opposite is true. No hysteresis curves have been obtained yet in compression.

*Hardness and Impact Strength**

Some tests at various temperatures showed that the average Vickers hardness of ½-in. titanium bar stock increased from 209 at 77° F. (25° C.) to 300 at −321° F. (−196° C.).

Keyhole-notched Charpy specimens prepared from ⅝-in. rolled rods broke with an absorption of 14.4 ft-lb. at 77° F. and 6.6 ft-lb. at −321° F. (Each of these values is the average of three tests: 11.6, 15.8, 16.2 and 6.2, 6.8, 6.8 respectively.) The Vickers hardness, measured on longitudinal surfaces of the Charpy specimens, was 255 at 77° F. and 418 at −321° F.

It may be noted that the hardness of the ½-in. bar at −321° F. is 300 Vickers, and the ⅝-in. rolled rods at −321° F. is 418 Vickers. Other data indicate that this difference may be of some significance, and may represent a difference to response to low temperatures. Both bars were from the same heat; both were finished by

*These data were obtained at Ohio State University, on contract with the Air Materiel Command.

Table II — Compressive Properties of Titanium Sheet

Condition	Direction of Rolling	Yield Strength (0.2% Offset)	Modulus of Elasticity in Compression
Annealed	Longitudinal	79,000 psi.	16,000,000 psi.
Annealed	Transverse	87,000	17,000,000
Cold rolled	Longitudinal	81,000	17,000,000
Cold rolled	Transverse	104,000	18,000,000

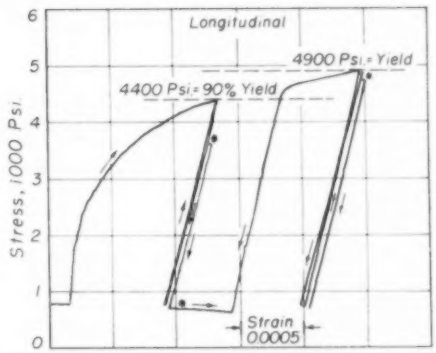


Fig. 3 — Typical Autographic Stress-Strain Curves for Annealed Aluminum Sheet (2S-O) of Tensile Strength 12,000 Psi., Yield 4900 Psi., Elongation 30.5% in 2 In.

hot swaging. The method of measurement was different. A disk was cut from the ½-in. bar, and the average hardness along two perpendicular radii is reported. The hardness reported for the ⅜-in. rod is the average of surface hardness of impact specimens cut therefrom, and therefore at the same depth below the original bar.

Longitudinal and Tranverse Properties

Test results from a single lot of titanium sheet are shown in Tables I and II. Each value is the average of two or more tests. The modulus of elasticity in tension was 17,000,000 psi., measured on annealed and cold rolled, longitudinal and transverse specimens. The modulus in compression (Table II) was determined from the autographic curves and hence is not so accurate as the modulus in tension, which was measured with both Tuckerman and Huggenberger instruments.

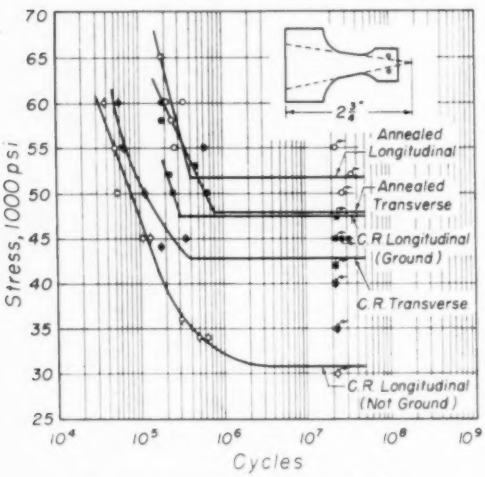


Fig. 4 — Flexural Fatigue of 0.063-In. Titanium Sheet, Annealed and Cold Rolled

Fatigue

Figure 4 shows fatigue data for both annealed and cold rolled titanium sheet. The extremely low fatigue properties for cold rolled, longitudinal specimens were improved by grinding about 0.02 in. from each surface, to minimize the effect of pits. No similar tests were made on the annealed sheet or on the cold rolled, transverse material. The higher fatigue limit of annealed titanium (tensile strength 96,000 psi.) over cold rolled (tensile strength 118,000 psi.) is rather surprising.

The fatigue curves of Fig. 5 were determined at Ohio State University on round, cantilever, non-rotating specimens. The ratio of fatigue strength at 10^7 cycles to tensile strength was 0.8 for unnotched specimens tested at room temperature. This is considerably higher than the ratio ordinarily observed for steel — about 0.45 to 0.55. All the fatigue strengths shown in Fig. 5 are comparable to those for steels.

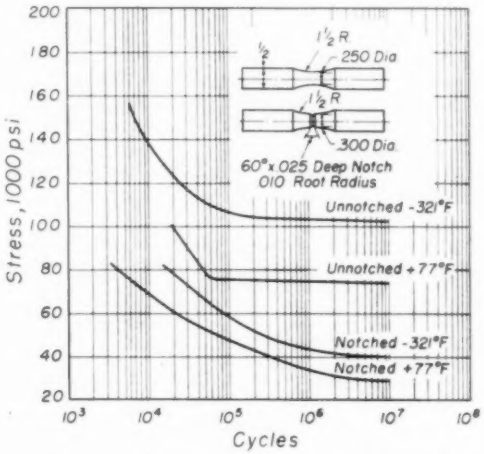


Fig. 5 — Flexural Fatigue of Forged and Swaged Titanium Bars, Notched and Unnotched

Tensile Properties at +77 and −321° F.

Specimens of 0.250-in. diameter, with 1.0-in. gage length, were tested at a crosshead speed of 0.025 in. per min. Averages for two tests at 77° F. were: Modulus, 16,700,000 psi.; tensile strength based on original area, 89,650 psi.; tensile strength based on area at failure, 133,500 psi.; yield strength, 72,150 psi.; reduction of area, 24%; elongation, 27.5% in 1 in. For two tests at −321° F. the same properties averaged: 18,960,000 psi., 186,500 psi., 221,500 psi., 177,000 psi., 14.75%, 13.75% respectively.

Similar specimens with a 60° notch, 0.025 in. deep (0.300-in. major diameter, 0.250-in. root diameter, 0.010-in. root radius) gave averages for two tests at 77° F. as follows: Tensile strength based on original area, 116,750 psi.; tensile strength based on area at failure, 124,500 psi.; reduction of area at root of notch, 12.5%; reduction of area outside notch, 7.75%; elongation, 5.5% in 1 in. For two tests at −321° F. the same properties averaged: 212,750 psi., 223,000 psi., 5.0%, 1.0%, 0.3%, no yield.

By I. R. Kramer
Head, Materials Branch
Office of Naval Research
Washington

Metallurgy Program of the Office of Naval Research

This article is devoted chiefly to ONR's program in metallurgy, which is the responsibility of the Materials Branch and is supplemented by work sponsored by our Mathematics, Physics, Chemistry and Mechanics Branches. It does not include the metallurgy research at the Naval Research Laboratory, nor the work conducted by the Navy's Material Bureaus. In other words, this article will center upon the forty ONR projects now underway at various academic and industrial institutions throughout the country.

The program is carefully integrated so that an effective exchange of ideas is attained between various investigators on related projects. The cross-fertilization of ideas is important to the advancement of metallurgy, for as the scientist becomes more and more specialized in a narrow area of a given field, he begins to lose sight of the talents and contributions of allied researchers in other fields. This is especially true in metallurgy where close cooperation of the metallurgist, the physicist, the engineer, the chemist, and the mathematician is often needed.

In the past, metallurgical research has been largely empirical because it dealt with real materials and all their accompanying vagaries. Since many of our physical laws apply to ideal phenomena, our actual materials are often too complex to permit direct application of concepts based on ideal substances.

There are, therefore, very large unexplored fields remaining to be studied where laws do not apply exactly. These fields must be explored carefully if we are ever to make use of the large accumulation of apparently unrelated data. The formulation of a satisfactory theory for some of the metallurgical phenomena will aid greatly in the solution of practical problems.

The Navy now knows that its difficulties in using the proper materials were due to a lack in fundamental understanding of the material under consideration. This lack corresponded, in general, with gaps in the research field.

THE SECOND World War taught the Navy that military engineering can best be advanced through the application of modern science. It taught that military preparedness and the solutions to many of its practical problems could best be achieved through the creation of a large store of basic knowledge upon which the Navy can draw. For these reasons, the Office of Naval Research (ONR) was permanently established early in 1946, by the Secretary of the Navy. Its mission was clearly described:

> " . . . . to plan, foster, and encourage scientific research in recognition of its paramount importance as related to the maintenance of future naval power, and the preservation of national security; to provide within the Department of the Navy a single office, which by contract and otherwise, shall be able to obtain, coordinate, and make available to all bureaus and activities of the Department of the Navy, world-wide scientific information and the necessary services for conducting specialized and imaginative research; to establish a Naval Research Advisory Committee, consisting of persons preeminent in the fields of science to consult with and advise the Chief of such office in matters pertaining to research . . . . "

At present, ONR is sponsoring a large research program in almost all of the major scientific disciplines. Its twenty-six branches administer projects in the physical, natural, mathematical, biological, and naval sciences, in addition to an active program in "human resources".

Plastic Flow and Fracture

One of the most difficult of present problems is the task of predicting the behavior of metals in service. After the metallurgist has completed his laboratory work on a new steel, for instance, what assurance does he have that a structural member made of that material will give satisfactory performance? For a simple analysis, the usual procedure is to postulate the behavior of an infinitesimal region of the member under the general combination of forces and then, by applying the fundamental laws of physics to the problem for any given geometry under fixed or variable forces, the problem can be solved in principle. Two major difficulties arise, however. One is that even with simple assumptions as to the behavior of a material under applied forces, the mathematical methods available have succeeded in giving solution only where the geometry is quite simple. The other difficulty concerns what behavior should be postulated when the deformations are large and when plastic flow sets in. The introduction of plastic strain into the metal immediately introduces an anisotropy factor resulting from that strain. This departure from perfect isotropy must be taken into account in any problem of plastic deformation, especially those involving combined stresses. For the examples studied so far, involving small strains, this anisotropy is not great, but neither are the effects of combined stresses resulting from bi-axial stresses. This problem remains unsolved for conditions of large plastic strains and tri-axial stresses. In addition, the laws governing the fracture of metals are still imperfectly understood. Probably less is known and understood about fracture than about plastic flow.

ONR is attacking the problems of plastic flow and fracture, not only from a macroscopic point of view but also on the basis of microstructure and crystal structure, and in relation to temperature, environment, state and degree of stress, strain rate, and prior strain history on the flow and fracture of metals. Since the metallurgical changes in a plastically deformed metal may affect its subsequent plastic behavior, a rather large portion of our work is being done with "simple" materials. Work is also underway to examine the initiation of slip in polycrystalline materials, as well as their behavior at the grain boundaries. In addition, there are studies of the movement of the atoms in the crystal lattice to explain the anelastic properties of metals and the yield point in iron. One investigation is examining the effects of dissolved alloying elements on the plastic properties of metals. Curves of effective stress versus effective strain for specially prepared high-purity aluminum alloys have been obtained in order to determine the influence of the alloying elements on the plastic properties. Considerable progress has been made in the correlation of plastic strains with atomic radii, concentration and the valence of added elements. Other studies include the behavior of metals under very high rates of plastic strain and the behavior of anisotropic materials under bi-axial stresses.

An important phase of our metallurgy program is concerned with studies on the fatigue of metals. It is not our intention merely to accumulate more data on fatigue properties, but rather to uncover the mechanism of failure and to study the effects of stress gradients, strain rate and geometry on the fatigue properties. Included in this work is a study of size effect in order to predict the behavior of large structures from small laboratory tests.

Transformation in Solid Metals

The mechanism and kinetics of reactions which occur in the solid state may be considered as the fundamentals of metallurgy. These are directly related to the mechanical and physical properties of metals. Emphasis in this field is being placed on the phenomenon of diffusion. Not only are the diffusion coefficients of various elements in iron, copper and aluminum being determined, but the mechanisms by which these elements diffuse are being used to explain the decomposition of austenite in the heat treatment of steel and precipitation in age hardening alloys. For these studies, use is being made of radioactive tracers to follow the metallurgical changes. Radioactive tracers are also being used to determine the vapor pressure of several metals and their alloys in order to evaluate activity coefficients. Attempts are being made to measure the carbon concentration in austenite at the pearlite-austenite interface during the growth of pearlite. The segregation of alloying elements during the decomposition of austenite is also being followed by radioactive tracer techniques.

One of the most useful metallurgical reactions is the transformation of austenite to martensite. For low or medium carbon steels, it has always been supposed that the austenite-martensite transformation is completed after the steel has been quenched. However, recent work on one of our projects has shown that steels containing as little as 0.1% carbon may retain 2 or 3% austenite at room temperature. The influence of the retained austenite on the subsequent behavior of quenched steel is not known, but it may impair the ductility of the steel if the austenite is unstable and later

decomposes. The increased reluctance of residual austenite to transform to martensite, at room temperature or slightly elevated temperatures, is still unexplained. This problem is being actively pursued, and the effect of plastic strain on the decomposition of austenite is being studied.

One of the problems that seems to have defied all attempts at solution is temper brittleness. Several common alloying elements increase the susceptibility to temper brittleness while others decrease this susceptibility. Temper brittleness is being studied in conjunction with careful control of the purity, chemical composition and melting practice and by subjecting the steels to controlled heat treatments.

Recrystallization and grain growth studies also occupy a part of our metallurgy program. These studies are being conducted with high-purity metals (aluminum, magnesium, copper, zirconium, beryllium) and are concerned with the effects of annealing temperature, time, chemical composition, and the influence of fiber texture and impurities.

A long-range program of fundamental research in all branches of science was started three years ago, in universities, research institutes, hospitals and industrial laboratories. The problems are usually suggested by the scientist who wishes to conduct the study; the function of the Office of Naval Research is to warn against unnecessary duplication and to provide some of the necessary money. The objective is to discover some new scientific principles, add to our basic knowledge about the laws already formulated, and to accumulate a reservoir of scientists for future work. Mr. Kramer describes these activities, as far as they apply to the science of metals.

Effects of Alloying Elements

The exact effects of alloying elements on the mechanical properties of steels have long been surrounded by mystery. A fairly good start has already been made in determining the effects of alloying on hardenability, tensile strength, yield strength, and resistance to tempering. However, very little work has been done on the influence of alloying elements on the ductility. In one of our projects, we are attempting to determine the effect of alloying elements on the transition temperature from fibrous to brittle fracture during impact. Specifically, we would like to know whether all steels have the same transition temperature and the same hardness when heat treated so that they have a completely martensitic structure after quenching prior to tempering, or whether the alloying elements *per se* exert an influence. If the alloying elements do exert specific influences, their effects will be determined. This type of problem is important to the selection of steels for particular uses. It may also help to reduce the number of steels currently in use.

Studies now being made on order-disorder transformations have greatly increased our understanding of such transformations. There is a definite possibility that they may be used as a tool to study other metallurgical changes due to atomic rearrangement. At present, order-disorder changes are being used to determine the movement of atoms in the crystal as a function of strain.

In a very recent project, a study is being made of the kinetics of phase transformations in titanium and titanium alloys. The allotropic change in titanium can probably take place by a martensitic-type reaction, similar to that found in zirconium and cobalt. After determining the nature of the transformation, the influence of alloying elements on the transformation characteristics will be investigated. Equilibrium diagrams for some of the titanium alloys will also be determined.

Corrosion

It has been estimated that the annual equipment loss to our economy as a result of environmental and chemical attacks runs to $6,000,000,000. The last war showed us the necessity for conserving the limited supply of our common structural metals. Although corrosion is a major problem to the chemical, mining, power, transportation, fuel and communication industries, it is most destructive to the Navy.

The corrosion and surface reaction program of ONR is devoted to the understanding of the mechanism and kinetics of corrosion reactions. Since most metals and alloys depend on the formation of protective surface films (passivation) for successful use under corrosive conditions at

normal and elevated temperatures, a major share of the program is aimed at furthering our knowledge of the mechanisms of passivation and the factors influencing the formation, nature and breakdown of protective films. Passivity studies on the stainless steels, iron-chromium alloys and titanium are being pursued intensively.

Another field of major interest is the corrosion and oxidation of metals and alloys at elevated temperatures. The performance of rockets, jet engines and guided missiles is dependent primarily on the development of oxidation resistant materials capable of withstanding extremely high temperatures and the erosive effects of hot gases. The alloy development program is being supplemented with several fundamental research projects aimed at better understanding of the mechanisms and kinetics of high temperature oxidation processes. In addition to the study of the more conventional systems such as the iron-chromium alloys, the processes occurring in the newer metals such as zirconium, titanium, molybdenum and beryllium are also being investigated. Diffusion mechanisms operating during oxidation are being investigated by radioactive tracers.

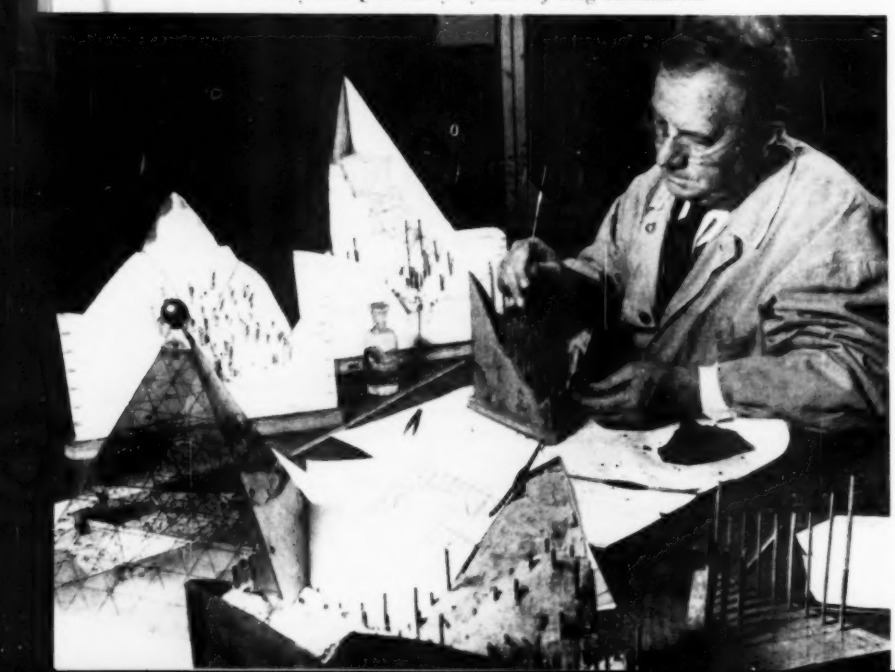
Despite the widespread use of inhibitors as anti-corrosive agents, little is yet known about the actual mechanisms by which they prevent corrosion. The mechanism of the inhibitor adsorption process, the effect of inhibitor molecule size and composition, and the conditions surrounding the adsorbed layer in corrosive mediums are still almost unknown. Thus, work is underway on the study of these problems as well as on the mechanism by which "passivators" (for example, nitrates, chromates, hexametaphosphates) afford corrosion protection.

Nor are the electrochemical fundamentals underlying corrosion processes being ignored. Studies on electrodes and electrode phenomena are underway, including the investigation of metal-solution interface potentials, contact potentials and the electrical double layer. Of great importance also is the investigation of the fundamental factors influencing bimetallic corrosion. Although this subject has received considerable attention in the past, it is still difficult to predict accurately the result of placing two or more metals in contact under a particular set of environmental conditions.

New instruments and techniques are being developed and utilized in several of these studies. In particular, the application of polarographic techniques has indicated considerable promise as a worthwhile approach to the measurement of corrosion rates.

The foregoing has provided merely a brief indication of some of the corrosion and surface phenomena being investigated. Considerable support to this program is being provided by allied research in such fields as electrochemistry, metallurgy, surface reactions, diffusion and other solid-state reactions. For example, although no specific project is underway on the study of stress-corrosion, studies on diffusion, flow and fracture of metals, and grain boundaries are accumulating knowledge which will aid in interpreting the stress-corrosion behavior of metals. An independent investigation is being undertaken on the fundamental nature of corrosion and the behavior of metals under stress. Ultimately this study can be adapted to the solution of stress-corrosion problems.

Ternary and Quaternary Systems of Slag Constituents



New Heat Resistant Materials

Heat resistant materials are of particular importance at this time. We are not now primarily concerned with the development of a new alloy but rather with the principles which govern the

behavior of alloys at high temperature. If we can uncover the fundamental principles governing creep, rupture and fatigue we may be able to apply these principles to the design of new alloys for use at high temperatures. Alloys are being thoroughly explored so that the influence of grain size, crystal structure, and microstructure on the stress-rupture, fatigue and creep properties can be determined. The effect of environment on the creep and stress-rupture properties are also being studied. Tests of polycrystalline materials are being made in an atmosphere of very pure argon, to which other gases are added in order to determine the effects of surface conditions on the creep properties. Single crystals of zinc are also being studied in various liquid mediums. These studies are seeking a better understanding of the role of surface imperfection and the propagation of slip resulting from these imperfections on the creep of materials.

In the search for materials for extremely high temperatures (above 3000° F.), attention has been given to intermetallic compounds having high melting points and good corrosion resistance. One ONR project is concerned with borides of the transition metals, such as chromium, titanium, molybdenum and tungsten. These borides have received almost no attention in the past. Therefore, the ONR program began with the methods of preparation of the borides in pure form. We are now concerned with equilibrium diagram studies. The mechanical and physical properties of compacts made by powder metallurgy techniques are also being determined.

In still another project, molybdenum and molybdenum alloys are being studied. At present the emphasis is being placed on arc-melted molybdenum. Melting equipment has been perfected which is capable of producing ingots weighing over 200 lb. The equilibrium diagrams for many of the binary alloys are being determined, and the mechanical and physical properties of these alloys are to be measured at temperatures up to 4000° F. Stress-rupture and creep apparatus has already been developed to carry out these measurements. As the ductility and forgeability of arc-melted molybdenum is greatly affected by small amounts of oxygen and carbon, methods of deoxidizing molybdenum are being investigated.

Chemistry of Steelmaking

In the near future, iron ores of much higher sulphur content must be utilized. The steelmaking capacity of the United States will then depend on the techniques for removing sulphur. Before substantial progress can be made, we must have a much better understanding of the chemical processes involved during the making of the steel. While considerable work has been done in determining the equilibrium constants of the important reactions, very little is known about the rates of reactions. This is in part due to the difficulties involved in the experimental techniques. ONR is among the first to sponsor a program on rates of reaction in liquid steel by the use of radioactive tracer techniques.

In this program the transfer rate of sulphur from the metal to the slag has been determined for simple slag systems, and the mechanism of this transfer has been outlined. Future work will seek information on the influence of other elements (such as manganese and silicon) on the rate of transfer. In nonideal solution, especially of the type found in the making of steel, it is not sufficient to use the percentage of components present in the slag or metal as a measure of the state of deoxidation or desulphurization. Not only is the quantity of material important, but the "activity" of the element in the presence of other chemical species may increase or decrease its effect. Hence, the activities of slag components are being studied.

Hydrogen exerts an appreciable influence on the properties of metals. However, the ability to control its presence or even to study its effect adequately has been hampered by the lack of rapid and accurate methods of analyses. A method for performing such an analysis in approximately 15 min. has been developed through one of the ONR contracts. It will be used to study the diffusion of hydrogen in solid steel and the rate of absorption in liquid steels. The effects of additions to the steel bath on the solubility is also being considered for future study. A program for the study of gases, including hydrogen, in solid metals is also underway.

Summary

The above is a general description of the ONR metallurgy program. It is the policy of this Office to encourage the publication of the results of our research in the various scientific journals. Such publication, it is believed, will do much to encourage further research and to stimulate interest in the many naval and industrial problems. Significant results from these fundamental studies are already having their effect on the metallurgical progress of this country. Every effort is being made to see that this progress continues. It is felt that the benefits of this research program are of value not only to the Navy but to industry and the population as a whole.

Correspondence and Foreign Letters

Modern Metals for River Boats

NEW YORK CITY

To the Readers of METAL PROGRESS:

Nine combination passenger and freight vessels, for use on the Yangtze River in China, have recently been built by two firms in Quebec. They include some highly specialized features, made necessary by the variable nature of the stream — currents up to 12 miles per hr. and depths varying from 7 to 20 ft.

It is believed that these are the first river steamers ever to be driven by steam turbines. Everything has been done to make them as safe as possible, not only in hull construction, double bottoms and unusual subdivision, but also every system has its standbys and interconnections. The entire superstructure, including stack, lifeboats, davits and stanchions, is made of aluminum alloys. A notable saving in weight, with corresponding reduction in draft, has resulted. This weight-saving principle has been extended to the hulls, which are built of "Cor-Ten", a high-tensile, corrosion and abrasion resisting steel. This resulted in a weight saving of 7%, inasmuch as Lloyds permitted a reduction of 10% in all scantlings over ¼ in. thickness. The slight extra cost of this higher grade steel is more than offset by increased payload.

PHILIP L. RHODES
Naval Architect & Marine Engineer

An Inhibitor of Pitting in 18-8

ST. CLOUD,
SEINE ET OISE, FRANCE

To the Readers of METAL PROGRESS:

Many tank cars, made of welded, passivated 18-8 chromium-nickel austenitic steel, are used on the French railroads for milk transport. Usually, their life is indefinite, but sometimes they start leaking within a year, due to the well-known and much-feared pitting type of corrosion. This concentrated attack generally occurs at some distance from the welds.

In service, these tanks are washed with water after being emptied of milk, and then filled about one third full of bactericidal solution of alkaline hypochlorite and sodium chloride — a solution that contains 300 to 400 parts per million of free chloride ions. This solution remains during the return trip, and may be in the tank for 15 to 20 hr. at temperatures running on a sunny summer day as high as 95° F.

Have any readers of *Metal Progress* any information on a reputed inhibitor for such corrosion? In the British *Journal of Dairy Research* for Jan. 1, 1949, C. H. Botham and G. A. Dummett contribute an article entitled "Corrosion by Commercial Sodium Hypochlorites and Its Inhibition", in which they recommend the addition, which has already been proposed by several American metallurgists, of sodium silicate (or silicate plus phosphate) as an inhibitor.

I have made some tests wherein 2.5 cu.cm. of sodium silicate was added to a liter of the hypochlorite solution, and have observed no trace of corrosion (either pitting or general) after several hundred hours immersion of 18-8 at temperatures up to 105° F., in various solutions containing 250 to 480 parts per million of free chloride ions.

Since the silicate in these solutions does not reduce notably their bactericidal power, they may be the corrective for the troubles with the milk tanks. However, pitting action is notoriously sporadic and hard to predict; in general one might almost say that "sometimes the metal pits, and sometimes it doesn't pit!" I would, consequently, like to hear from any American metallurgist who knows whether these inhibitors have been used industrially in the U. S., and whether or not the results have been satisfactory.

A. SOURDILLON
17 Rue l'Aqueduc, St. Cloud

Baby Bikini

ANTON D. BRASUNAS, research engineer at Massachusetts Institute of Technology, sends this micro at 40 diameters, taken by Prof. H. R. Spedden. It is an eruption of oxide scale on 80-20 Ni-Cr alloy, heated at 2100° F. "In contrast with the split-second Bikini mushroom, this oxide was grown in one week," writes Mr. Brasunas.

Preventing Bacterial Growth in Oil Emulsions

MIDLAND, MICH.

To the Readers of METAL PROGRESS:

Bacteria will shut down a hydraulic press.

The department of Dow Chemical Co. which manufactures wrought magnesium products operates large extrusion presses which utilize an oil emulsion for hydraulic fluid. In common with other emulsifiable oils, this fluid supports the growth of bacteria, evidenced by sludge formation, blackening of the emulsion, evolution of H_2S, and breakdown of the emulsion. Frequent shutdowns of the hydraulic system from such causes resulted in considerable loss of valuable production time.

Such troubles are common to emulsions used for coolants and lubricants in various cutting, grinding and forming operations. (Bacteria will not grow in straight or insoluble oils used for such purposes, nor in emulsifiable oils before dilution.)

The source of contamination will vary with the particular use of the emulsion. In an open system such as that used in a cutting or grinding operation, the contamination may be due to bacteria in the air, on workers' hands or waste material, while in a closed hydraulic system the major source may be the water supply — more bacteria are introduced each time water is added to replace leakage from the system.

Most emulsifiable oils when diluted 1 to 5 or more will support bacterial growth and require the addition of a preservative. In turn, the compatibility of the preservative with the emulsion will determine the type of preservative that can be added. Some compounds will cause a separation of the emulsion. Other compounds may give an odor or cause a color change, undesirable in some instances.

Furthermore, the solubility of a given preservative in an oil concentrate will determine the extent to which that oil can be diluted and still retain a bacteriostatic concentration of preservative in the emulsion — that is, one that prevents further growth of bacteria.

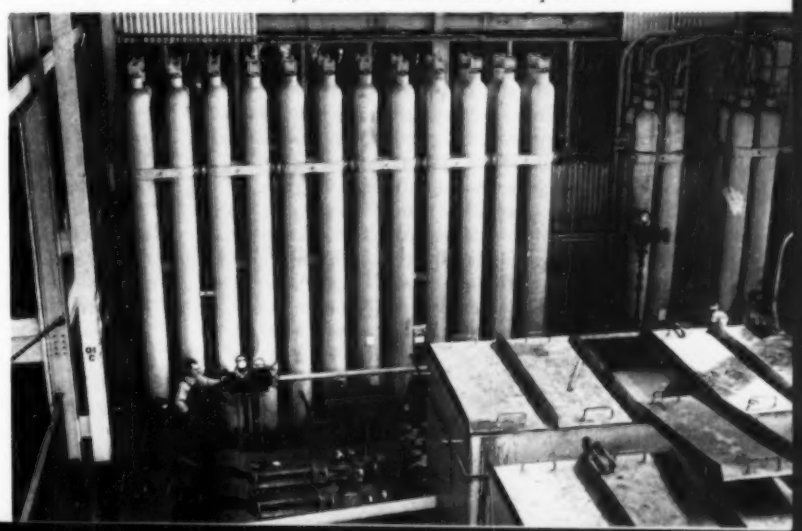
After some study of the above problem, Dow Chemical Co. has developed a series of phenolic compounds for germicides or preservatives. Two of them, *o*-phenylphenol and 2, 3, 4, 6-tetrachlorophenol, are oil soluble and have been widely used as preservatives by the manufacturers of germicidal emulsifiable oils.

They are also available to users in the form of water-soluble sodium salts.

To correct the difficulties in our own extrusion department, mentioned above, we found that sodium *o*-phenylphenate would preserve the emulsion at a concentration of 0.1% by weight of the total amount of the emulsion. Samples taken three days and two weeks later both showed that the emulsion was free of bacteria.

A month passed during which time the hydraulic system was trouble-free and it became necessary

Central Hydraulic Fluid Storage and High-Pressure Reservoir Cylinders in Extrusion Department



to add more emulsion to the 16,000-gal. system because of the fluid losses. No addition of sodium *o*-phenylphenate was made when the additional emulsion was poured into the tank. The results of diluting the preservative became apparent 10 days later when emulsion breakdown and clogging of the screens occurred. At that time bacterial counts showed that over 400,000 bacteria were present per milliliter of emulsion. One week later further tests showed that the emulsion now contained 4,000,000 bacteria per milliliter. The concentration of sodium *o*-phenylphenate was then returned to 0.1%, and tests made three days later showed that the emulsion was once again free of bacteria.

It is now the standard operating procedure in Dow's wrought products department to maintain an effective concentration of the preservative at all times in the hydraulic fluid.

W. M. Westveer
Biochemical Research Lab.

J. S. Brosier
Dowicide Sales Div.
Dow Chemical Co.

Stress-Strain Relations

Amsterdam, Holland

To the Readers of Metal Progress:

In *Metal Progress* for May 1949, p. 700, M. G. Corson abstracted and criticized my paper on "Stress-Strain Relations for Uni-Axial Loading", and I believe that several of his criticisms are unjustified. In the original paper, I wrote as follows:

"From equations 12 and 13 follows

$$\tau = \tau_t - (\tau_t - \tau_c)e^{-mk_2\eta_c} \qquad (14)$$

"Replacing maximum shear stresses by normal axial stresses and mK_2 by 1 η_c, we obtain:

$$S = S_t - (S_t - S_c)e^{-\eta/\eta_c} \qquad (15)"$$

In his review, Corson says that the mathematical transition from equation (14) to equation (15) is not justifiable. I should like to justify the transition. Assuming that the shear-stress equation for the two-dimensional system is correct, the same equation fundamentally holds for the three-dimensional case of uniform uni-axial loading. The latter case can be assumed to consist of two two-dimensional systems with coinciding axes of positive strain and perpendicular axes of negative strain, or, if preferred, of an infinite number of two-dimensional systems with the axes of positive strain coinciding and the axes of negative strain distributed at random. Since in uniform uni-axial loading the true normal stress is twice the principal shear stress, the normal stress equation therefore follows directly from the shear-stress equation.

According to Corson, the physical meaning of the characteristic strain η_c is quite obscure. I fail to see why this constant is more obscure than any generally accepted constant. Together with the asymptotic (maximum true) stress S_t it completely characterizes the strain hardening behavior of the metal in static loading and at a given temperature. Corson remarks that this asymptotic stress is a phantom which can never be reached. However, this stress is almost reached and can therefore be measured with accuracy for very plastic metals, drawn through dies to high uniform strains.

I am not sure what Corson means by saying that "a really worthwhile formula would give the maximum true stress for a finite strain of definite physical meaning". If recrystallization or similar effects are excluded a maximum true stress will never be reached at a finite strain, neither in the case of uniform straining, nor in the case of necking, where even the effect of the increasing triaxiality more and more surpasses the effect of strain hardening. I do not feel any fundamental difference in the gliding and strain hardening mechanism of the crystals before and beyond the point of maximum load. The occurrence of necking is simply a matter of mechanical instability and depends on the state of stress. A similar instability does not, for instance, occur in compression, though the strain hardening behavior is quite the same. Moreover, with a tensile testing machine of high rigidity (even a normal hydraulic machine is suitable), equilibrium can practically be maintained during necking and "a specific type of kinetic energy" therefore plays no part of any importance.

Corson wrongly suggests that the acceptance of formula (15) would force one to accept the existence of a mechanical equation of state. The existence of such an equation of state was not considered in my paper, and is not necessarily a consequence of the stress-strain relations derived by Van Wijngaarden and myself.

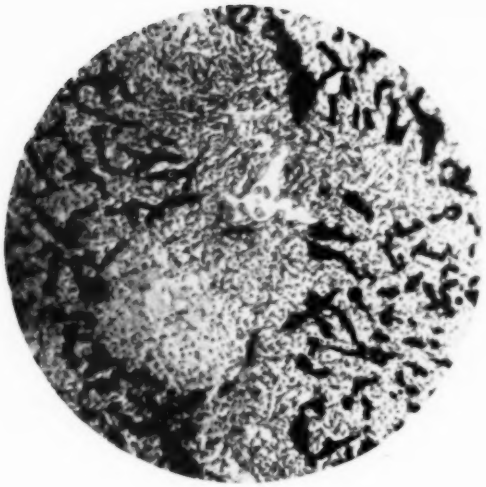
J. H. Palm
National Aeronautical Research Institute

Steaditus Malignus

Chicago, Ill.

To the Readers of Metal Progress:

Recently we came upon a heat of ferritic gray iron which did not harden when given a heat treatment which had been satisfactory with previous lots of apparently similar chemical analysis and microstructure. An exhaustive examination revealed, in a water-quenched and drawn specimen, a gremlin of the rare type, *Steaditus malignus*. (A near relative, *S. innocuus*, is com-



monly found in gray iron, but is both harmless and featureless.)

This bothersome creature was entrapped, neck-deep, by the rapid transformation. The violence of his struggles is attested by the three-way microcrack southwest of his shrieking mouth, at approximately the point where his feet are probably buried.

It is hoped that this may cast a new and helpful light on the causes of low hardenability and microcracking in metal that otherwise contains the usual constituents.

HELEN HOOVER
Metallurgical Section
Manufacturing Research Department
International Harvester Co.

Metal Powder and Hard Particles Made Into Steel-Backed Bearings

NEW YORK CITY

To the Readers of METAL PROGRESS:

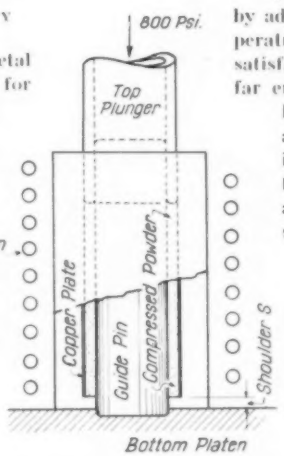
The process of hot pressing of metal powders described in *Metal Progress* for March 1947 has been extended to the pilot plant manufacture of steel-backed bearings wherein the "anti-friction" material may be one of numerous combinations of powder metals, carbides and borides. These bearings are required to operate at high temperature and extreme speeds without galling or binding. Ordinarily they run without oil, but sometimes are slightly grooved to hold a graphitic lubricant. Some high-temperature lubricant is added to the mix, equal in amount to about 5% of the copper content. Some of the bearing combinations have been:

	No. 1	No. 2	No. 3	No. 4	No. 5
Cu	55	25	25	20	10
Ni	25	25		20	50
Co	10	15		20	
Mo	2			5	
Al				10	
TiH_2	5	10		20	
Carbides and borides	25		75	5	40

The sketch shows the method of manufacture. The die which holds the metal powder remains as the steel backing sleeve of the bearing. It is machined to correct dimension, long enough for the supporting shoulder S at the bottom of the cavity. It is ordinarily of high alloy die steel. The interior bore is copper plated to aid the anchorage between sleeve and liner.

This sleeve is placed on the lower platen of the press within an induction coil. The guide pin, slightly longer than the die, is then dropped into the snugly fitting hole at bottom, and the cavity filled with the powder mix. Then pressure is applied by the annular top plunger, acting as a ram, meanwhile heating the mass with high frequency energy induced by the coil. Sintering requires about 25 sec. at pressure of about 800 psi. The guide pin is then knocked out, the sleeve machined to length, and the bearing surface diamond bored.

HARRY L. STRAUSS, JR.
Technical Director
National Diamond Hone & Wheel Co.



Blast-Furnace Control Via the Tuyeres

LONDON, ENGLAND

To the Readers of METAL PROGRESS:

Blast furnaces are controlled usually by adjustments in the burden, blast temperature and wind volume. This has been satisfactory up to a point, but does it go far enough? A further way of controlling the flow pattern in the stack, and thereby its operation, is to modify the extent of combustion zone in front of the tuyeres. Some years ago, it was suggested by Steudel that small quantities of lime might be admitted with the blast, although little practical work was done at that time.

The subject was reopened by the ironmaking division of

the British Iron and Steel Research Assoc. last fall, following a series of theoretical investigations which suggested that there was a thermal surplus in the furnace. Preliminary trials have shown that substantial quantities of lime — at rates (over short periods) up to one ton per hour — can be injected at one tuyere without detriment. This is greatly in excess of, say, 5% of the total needed to effect a fine control of slag basicity. The advantage lies in the possibility of making immediate adjustments without the necessity, as at present, of having to wait from eight to ten hours before material charged at the top can work down to where it can become effective; moreover, it would materially reduce the usual swings in slag composition.

Some further experiments have shown that the immediate destination of the lime can be varied by changing the particle size, thus opening up the possibility of fluxing the coke ash as it is liberated, or of controlling bosh slags.

With a suitable design of injector tuyere, there are, however, indications that its possibilities may be extended still further. Preparations are now in being to use this medium as a means of introducing *(a)* additional iron units into the furnace in the form of flue dust or concentrates; *(b)* a proportion of the total fuel in the form of small coke, oil or gas, particularly in the event of possible shortages of good blast furnace coke; and *(c)* high pressure air or oxygen to modify the combustion zone with the object of controlling voids in this region, and so providing means by which the bosh temperature distribution and downward flow of the stock between wall and center can be regulated.

TOM BISHOP
Metallurgical Editor
Iron and Coal Trades Review

Bambi

OTTAWA, ONT., CANADA

To the Readers of METAL PROGRESS:

Either Bambi or a relative is taking a stroll through a field of austenite but is a little frightened at some imagined danger lurking in some carbide moss.

DONALD A. SCOTT
Bureau of Mines

Ferrite Islands Outlined by Films of Sigma Phase in Austenitic 29-9. 1500×. NaCN electrolytic etch

Hydrogen in Cathode Nickel

NEW YORK CITY

To the Readers of METAL PROGRESS:

Hydrogen is not always detrimental. In cathode nickel, hydrogen is apparently responsible for increased ductility. For example, I tested some metal in the form regularly produced by the American nickel refineries. I do not know how much hydrogen the cathodes contained, but when test bars weighing a total of about 250 g. were annealed at 1600° F. while enclosed in an iron pipe, a torch of hydrogen flame shot out of the pipe and burned for many minutes. In spite of that amount of occluded gas, the density of the original cathodes was rather close to the maximum; among six test bars the minimum density was 8.90 and the maximum 8.94. (Metals Handbook gives 8.90.)

Brinell hardness of the cathodes was uniform — 187, in comparison with about 60 for annealed nickel. Other mechanical characteristics were also high and uniform. The tensile strength was 88,000 psi. — an average of eight tests, with a variation of 2000 psi. both ways. Elongation in 2 in. was 29 to 35%, with the average at 32, and reduction in area averaged 66% ±4.

Annealing at 800° F. produced no noticeable evolution of hydrogen, but the hardness dropped to between 90 and 110, and the tensile strength to 72,000 psi.

Ductility was not impaired after annealing at 800° F.; density was not changed.

Annealed at 1600° F. with a copious evolution of hydrogen, the metal scarcely lost as much as 0.15% in density, but the hardness dropped to between 50 and 60, tensile strength was from 43,000 to 46,000 psi., elongation 15% and reduction in area 20% (still substantial).

Interesting also was the behavior in the Izod test. Not a single (standard notched) bar opened up; bending it to the point where the hammer could pass took from 73 to 98 ft-lb. (This is for the metal as received.) Annealing at 800° F. did not change the figures, nor did the bars open up to any extent. But annealing at 1600° F. — a rather harsh treatment — dropped the Izod value to between 43 and 54 ft-lb., and cracks were started, although no complete break occurred. The characteristics

(Continued on p. 386)

WHAT'S THE

Important Difference

BETWEEN

Carbon Steels and Alloy Steels?

No SINGLE characteristic denotes the real difference between alloy steels and carbon steels.

Certain of the most useful mechanical properties—strength, hardness, toughness, ductility—can be developed to a high degree, individually *but not collectively* in carbon steels.

Nor can such desirable characteristics as response to mild quenching, high strength and elastic properties in large sections, and good resistance to distortion and cracking in heat treatment of complex shapes be developed in carbon steels.

In nickel alloy steels *all* of these characteristics can be obtained, in greater or lesser degree, *at the same time*. From among the many grades of standard alloy steels containing nickel it is possible to select one which provides the best set of properties for meeting virtually any reasonable requirements.

Yes, in the final analysis, it is the better, more complete *combination* of properties—and, therefore, better performance and long-range economy—available in the nickel alloy steels which constitutes the most significant difference.

We shall be glad to furnish counsel and data to help you select the right nickel alloy steel for your requirements.

EMBLEM OF INCO SERVICE

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK 5, N. Y.

September, 1949; Page 360-A

Properties of Heat Treated Alloy Castings

After Tempering at 1200° F.; Micros at 75×. *By J. B. Caine and R. S. Haught*

Code for mechanical properties: First two figures are ultimate tensile and yield strength in 1000 psi.; next two figures are elongation in 2 in. and reduction of area in %; last figures are Charpy keyhole test at temperatures noted.

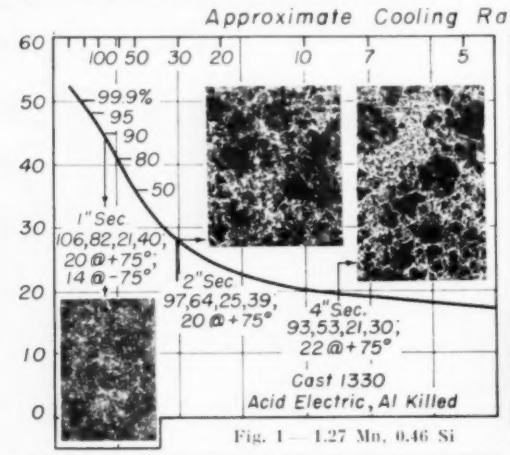


Fig. 1 — 1.27 Mn, 0.46 Si

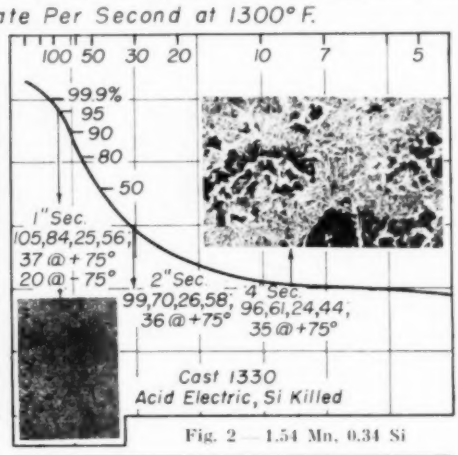


Fig. 2 — 1.54 Mn, 0.34 Si

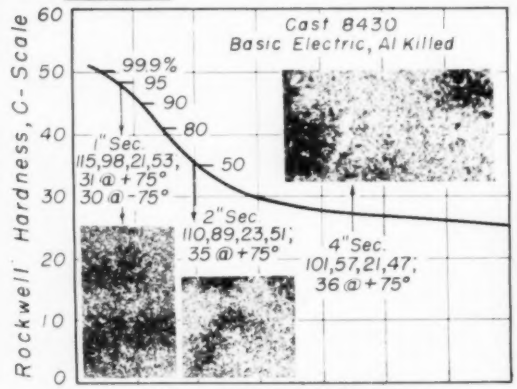


Fig. 3 — 1.30 Mn, 0.48 Si, 0.38 Mo

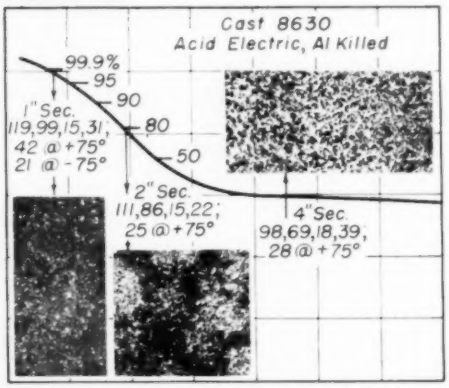


Fig. 4 — 0.80 Mn, 0.45 Si, 0.53 Cr, 0.70 Ni, 0.20 Mo

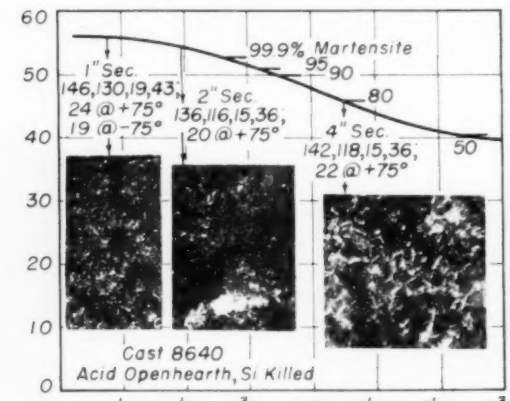


Fig. 5 — 0.77 Mn, 0.44 Si, 0.57 Cr, 0.69 Ni, 0.18 Mo

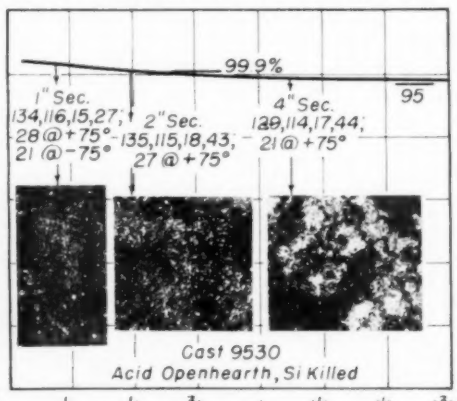


Fig. 6 — 1.39 Mn, 0.38 Si, 0.62 Cr, 0.64 Ni, 0.41 Mo

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Metal Progress: Page 360-D

By J. B. Caine
and R. S. Haught
Metallurgists
Saubrook Steel Castings Co.
Lockland, Ohio

Slack Quenching Versus Quench Cracking

THEORY is a wonderful thing — sometimes. Sometimes it can be awfully aggravating. Take hardenability for example. There can be no question that the ultimate in mechanical properties is obtained with a fully martensitic structure (after tempering, of course). Tempered martensite means that the steel must be "quenched out", quenched to 100% martensite if possible. Not only quenched at a rate fast enough to "pass the nose of the S-curve", but contain sufficient alloy to push the nose of the S-curve far enough away from zero time that no part of the cooling piece will intersect the curve (transform to something besides martensite).

In this instance, theory, as usual, crashes head on with practical difficulties, even when dealing with relatively small test specimens. There is much argument as to whether a hardenability specification shall be written to insure 80 or 50% martensite on the quench. Full martensite (100%) is ignored almost automatically as being the impractical perfection. The problem is complicated further in production by nonuniform sections and variation in cooling rates inherent to this nonuniformity. Such nonuniformity of shape, plus high hardenability of the steel, too many times equals quench cracking.

Consider now the lot of the poor metallurgist: The perfectionist (in this case the customer) insists on maximum mechanical properties. The boss insists that the part come from the quench in one piece. The cost department objects to more alloy, not only because of increased cost of the steel, but also the higher machining cost. To satisfy the perfectionist, our hero not only has the cost department on his neck, but flinches every time a piece is quenched, expecting to hear that heart-rending "ping" that signifies that the part is no longer in one piece.

Of course there are tricks that can be used to minimize the number of these "pings", such as time quenching, austempering, martempering, blocking, and several others. They all have one objection in common — they all cost more than a simple oil or water quench. Most of our hero's troubles would be over if every heat treating department had a hot quenching tank. But just imagine the reaction of the average plant manager to the cost of such an installation with its heat exchangers and hot salt pumps, a tank just capable of cooling a 50-lb. piece at the rate of oil, much less water.

The average heat treater and metallurgist must therefore, for some time to come, fall back on some type of time quenching, plus a lot of luck if he must satisfy the perfectionist who demands the theoretical 100% tempered martensite as a final structure. Life would be much easier, the heat treatment and steel appreciably cheaper, if the part could be slack quenched to, say, under 80% martensite. This is especially true when the part to be quenched becomes larger and more complicated.

The question boils down to this: "How are the mechanical properties of steel affected by slack quenching? What are the properties to be expected at various martensite levels on quenching?"

First, there can be no argument that if the part requires high hardness for wear resistance or any other reason, or high strength that is dependent on high hardness, the part must be quenched to this hardness. On the other hand, many parts are being quenched to high hardness and high martensite, only to be tempered at relatively high temperatures to relatively low hardnesses. Is this really necessary? All advantages

are in favor of less alloy and slower quenching rates if the resultant properties are acceptable to the designer and will satisfy the serviceability of the part. (The last-mentioned contingency should satisfy the designer and customer.)

In our experience, most of the demand for high quenched hardness, regardless of the hardness specified after tempering, arises from a fear of poor mechanical properties, especially those measuring so-called ductility. Many investigators[1]* have shown that there is a significant difference in mechanical properties of steel due to differences in microstructure and quenching rate. Let us examine the evidence a little more closely, especially as it relates to cast steel (since most published work has been done on rolled or forged specimens).

Herres and Lorig have confirmed the well-known fact that tempered martensite has much higher notched impact strength than pearlitic and bainitic structures resulting from slower cooling rates. However, the question under discussion is not differences due to microstructures resulting from greatly different cooling rates (as for liquid versus air or furnace cooling), but the effect due to much smaller differences in cooling rates as the result of increasing section sizes. The effect of these smaller differences seems to have been neglected in the past.

Grossmann[1] and others have shown that the presence of small amounts of pro-eutectoid ferrite, interspersed in a hard martensitic matrix, drastically lowers the resistance to stress concentration as measured by the notched impact test. One point seems to have been overlooked. The primary ferrite in these investigations has been rejected *isothermally* (as in austempering) and may or may not have the same effect on the mechanical properties as that ferrite rejected in continuous cooling in a quench tank. Then, too, most of the published work has been on steels of high hardness, tempered to low temperatures, if tempered at all; steels exhibiting maximum variation in the hardness of their constituents — small areas of very soft ferrite interspersed in a matrix of very hard martensite. Perhaps the reason for their poor mechanical properties is not primarily the microstructure, but variations in hardness and physical properties of the microconstituents — at least this might be concluded from the work on cast steels of Timmons[2], who found that improved mechanical properties follow, primarily, physical uniformity of the microconstituents.

This point is important to make, if for no other reason than to take the operating metallurgist off the spot. It is doubly important as the size and complexity of the part increase. If the ferrite rejected during slack quenching does not decrease the mechanical properties after a relatively high tempering treatment, it would be well to know it, for too many times the operating man must make a choice between slack quenching and quench cracking. He rightly chooses slack quenching as the lesser of two evils, for no matter how theoretically perfect the microstructure, the part as a whole is worthless if cracked. Even if the final maximum of properties cannot be achieved, is it not better from all standpoints to sacrifice maximum to known and acceptable properties, rather than to be in constant danger of quench cracking?

This point becomes of prime importance in quenching steel castings, simply because they are almost invariably complex. It is not too unusual to find half-inch sections adjoining 5-in. sections. Such extreme nonuniformity enhances the danger of quench cracking. Under such conditions it is imperative to know what the properties will be, not after quenching at the fastest rate possible, but at the slowest rate that will result in an acceptable part.

Fortunately, most of the work to determine this point for low-alloy cast steel has been performed[3] by M. F. Hawkes of Carnegie Institute of Technology for the Steel Founders Society of America and his test specimens were available for microscopic study. Hawkes and Brown have reported on the relationship between microstructure and mechanical properties of cast steel cooled at various rates from drastic water quenching to very slow furnace cooling. The work of the present authors complements that work in the more restricted range of cooling rates from those obtained in still air to those obtained by water quenching, and it extends the former work to a greater number of types of cast steel quenched in a number of section sizes. We are indebted to Dr. Hawkes, who very kindly furnished the specimens used in his original investigations, whose properties in tension and notched impact are known. The writers' role is confined to the microscopic examination of the broken impact specimens cut from the centers of the quenched 1, 2 and 4-in. cast sections.

In all, 32 heats of low-alloy cast steel made by 32 different foundries were investigated. The carbon range extended from 0.20% in Type 8620 carburizing cast steel to 0.40% in Type 8640 oil hardening steel. The hardenability curves varied from the sharply dipping curves of Type 1330 to almost horizontal lines for air hardening cast steels of the 9530 class. The steels were made by the four common melting practices — acid and

*References will be found on p. 399.

basic openhearth, acid and basic electric. Some were silicon killed and inherently coarse-grained; some were aluminum killed and inherently fine-grained. However, all showed an A.S.T.M. austenitic grain size of 5 or finer at the heat treating temperatures used, except one with a 4½ grain size. The results are therefore quite comprehensive as to the mechanical properties of cast steel, heat treated in sections up to 4 in.

As hardenability tests were made on all the steels, it is convenient to illustrate the mechanical properties and the microstructures at positions corresponding to the theoretical cooling rates for the centers of the 1, 2 and 4-in. sections, thus visualizing the properties at their centers, and also establishing the cooling rates necessary for any given mechanical requirements of irregularly shaped parts, or for other quenching media (providing the cooling rate and hardenability are known).

Experience seems to indicate that brittle failures in service (coarse crystalline fractures with negligible plastic deformation) occur only in steels whose Charpy impact at service temperature is less than 10 ft-lb., and is independent of microstructural constituents and their distribution. The authors, therefore, argue that "slack quenching" — as is inevitable in thick sections even during the most drastic quench — should be permissible for the vast majority of steel castings, plain or alloyed, since it gives far better Charpy values than annealing. In fact, slack quenching is far more desirable than risking cracks in an effort to quench out to 100% martensite.

The data sheet, p. 360-B, contains six charts correlating cooling velocity from the austenitizing temperature with the properties and microstructure of low-alloy cast steel, made and killed in various practices. Mechanical properties at the center of the designated sections accompany the photomicrograph. To save space these are in simple code: 106, 82, 21, 40; 20 @ +75°, 14 @ −75° means tensile strength 106,000 psi., yield strength 82,000, elongation in 2 in. 21%, reduction of area 40%; Charpy keyhole impact 20 ft-lb. at +75° F., 14 ft-lb. at −75° F. (V-notch Izod impact tests were also made, but as there was good correlation between the two only the Charpy values are listed.) Properties and microstructures are those resulting from a 1200° F. temper following a water quench at the rate noted in the charts.

Cooling rates given at the top of the diagrams are taken from Scott's work.[4] Correlation between Rockwell hardness and per cent martensite is taken from Hodge and Orehoski.[5]

The two carbon-manganese 1330 steels of Fig. 1 and 2 (p. 360-B) illustrate a number of important points. They have almost identical chemistry and hardenability; nevertheless there is an appreciable difference in resistance to brittle fracture (Charpy test) and microstructure. However, the steel of Fig. 1 with the more uniform structure and less ferrite has *lower* mechanical properties than Fig. 2 with a more segregated structure and more primary ferrite. This is not an unusual condition; it occurs throughout this study, although to a lesser degree. There seems to be no correlation between the microstructure and either tension or notched impact properties that measure ductility. In fact, many of the seemingly segregated cast steels show the better properties.

Factors other than microstructure have a greater effect on the mechanical properties. The difference in the ductility of the two cast steels of Fig. 1 and 2 is due to a difference in the inclusion pattern; Fig. 1 contains so-called Type II sulphide inclusions in strings rather than randomly oriented as in the steel of Fig. 2. You cannot change the inclusion pattern no matter how fast you quench.

Variations in mechanical properties that could not be attributed to inclusion pattern were found to a lesser degree in other steels. However, in no case could they be attributed to microstructure. Additional discussion can be found in Hawkes' work, Reference 3 (see p. 399).

Addition of molybdenum to a carbon-manganese steel results in a slightly higher hardenability curve (see Fig. 3, p. 360-B, for a Type 8430 steel). Note the excellent mechanical properties — especially those measuring resistance to rupture — accompanying what seems to be a highly segre-

	Cast 8640 (Compare Fig. 5)		Cast 9530 (Compare Fig. 6)	
	A.C.; D. 1200	W.Q.; D. 1200	A.C.; D. 1200	W.Q.; D. 1200
Tensile	128,000	142,000	121,000	129,000
Yield	78,000	118,000	97,000	114,000
Elongation	15	15	15	17
Reduction	34	36	39	44
Charpy +75°	3	22	3	21

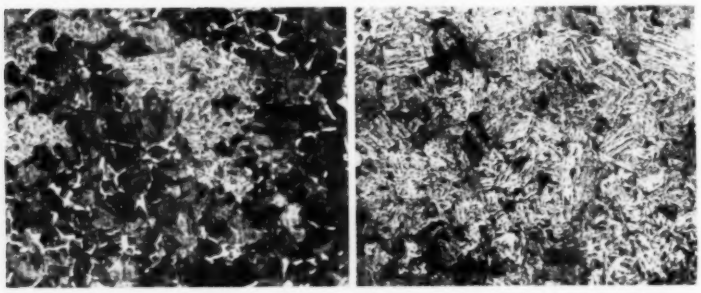

Fig. 7 — Normalized Microstructures Associated With Low Charpy Tests. Acid openhearth steels, 4-in. sections, air cooled (A.C.), drawn at 1200° F.

gated structure in the larger sections. In fact, the notched impact strength of the 2 and 4-in. sections is higher than the 1-in. section that exhibits the more uniform microstructure. This increase is due to the slight decrease in tensile strength and hardness; it is just as if the microstructure were uniform throughout the series.

The next increment in hardenability was obtained with a triple-alloy cast steel of the 8630 type. Figure 4 illustrates one of the four steels of this type that were investigated. Again, there is no marked difference in the mechanical properties attributable to difference in microstructure, especially in tensile ductility and notched impact strength. (Only minor differences in the microstructure were observed in the four heats made of this analysis by the four melting processes.)

The effect of increasing carbon 0.40% with this particular analysis is illustrated in Fig. 5, a silicon killed steel made by the acid openhearth process. Again, any difference in microstructure due to variations in quenching rate within the range under discussion has no appreciable effect on so-called ductility (as measured by tensile elongation and reduction of area) and resistance to brittle failure as measured by Charpy keyhole notched impact.

The cast steel of the highest hardenability studied corresponded to Type 9530, whose hardenability curve is practically a horizontal line (Fig. 6). There is, again, little difference in "ductility" values for the three sections and three cooling rates from the austenitizing temperature, but it is interesting to note that these steels of high hardenability are the only ones that do not exhibit an appreciable decrease in the ratio between yield and tensile strength as the section size increases above 1 in., with a corresponding decrease in the cooling rate during quenching.

The heats illustrated on p. 360-B are representative of the 32 heats studied. With the exception of Fig. 1 and 2, which were selected as extremes, the sole criterion of selection was that the mechanical properties be determined completely for all sections and with all heat treatments. All of the 32 heats were examined microscopically, but have not been reported due to space considerations.

Effect of Quenching Rates

It should be possible to draw definite conclusions from this study as to the effect of quenching rates, within the range studied, on the mechanical properties and microstructure.

Cast steel microstructures resulting from quenching rates between 100 and 7° per sec. at 1300° F. have no appreciable influence on those properties measuring resistance to brittle fracture — that is, the notched impact strength and, secondarily, tensile elongation and reduction of area. In fact, many of what seem to be the more segregated microstructures gave the higher values. This statement has been proven for all sections up to 4 in. and for all properties at room temperature. It is also true for 1-in. sections tested in notched impact down to temperatures of −75° F. (No subzero impact tests were made on specimens cut from the 2 and 4-in. sections.)

There was no correlation between the shape of the hardenability curves and notched impact strength or tensile ductility. It may seem that these statements conflict with accepted thought. For example, Crafts and Lamont[1] have shown a decrease in notched impact strength of wrought steel as the quenching rate decreases, but for all practical purposes, the decrease in notched impact strength is not alarming until the quenching rate is lower than the low limit of this paper (7° F. per sec. at 1300° F.). For example, Crafts and Lamont have shown that slack quenching to a Rockwell hardness as much as 25 points lower on the C-scale than when quenched to 100% martensite decreases

the Izod notched impact strength an average of 20 ft-lb. (roughly equivalent to 8 ft-lb. Charpy impact strength at the higher values). This is within the range of accuracy of the test itself. Not until the quenched hardness decreases more than 30 units on the Rockwell C-scale below the ultimate obtainable do the impact strengths decrease to dangerously low values. This corresponds to hardnesses obtained by air quenching the steels and section sizes studied. Some of our cast steels also show unacceptable impact values in heavy sections when air quenched.

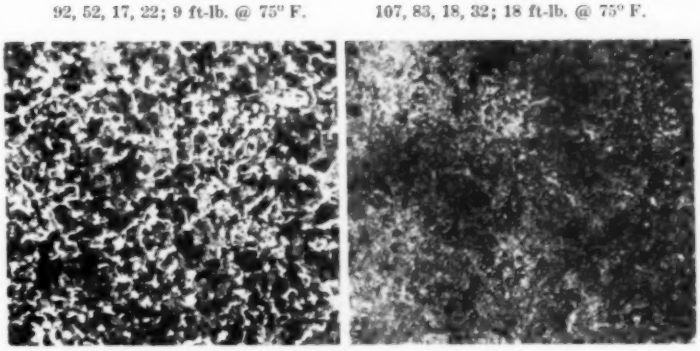

Fig. 8 — Normalized Microstructures Associated With Better Charpy Tests. Acid electric steels, 4-in. sections, air cooled, drawn at 1200° F.

Hawkes and Brown[3] show a similar condition existing in cast steels. Although mixed microstructures resulting from cooling rates less than those required for 100% martensite do result in decreased ratios of tensile strength to impact values, the decrease is not alarming (about 5 ft-lb. Charpy) until the cooling rate from the austenitizing temperature is decreased below about 40° F. per minute (0.7° F. per sec.), a cooling rate on a different order of magnitude than the lowest (7° F. per sec.) discussed in this article.

How Much Toughness Is Needed?

This brings up the question, "What are acceptable and unacceptable impact values?" There are definite correlations reported in the literature between brittle service failures and notched impact strengths of 10 ft-lb. or less at the working temperature (failures usually occur below room temperature). Such service failures are usually associated with a coarse crystalline fracture and it is significant that the same type of fracture is found in the impact test when the specimen breaks at less than 10 ft-lb., regardless of the test or specimen used. From the practical standpoint of the authors, 10 ft-lb. is a necessity; values much in excess of 10 ft-lb. are a luxury until proven to be needed. We have been unable to find any reference in the literature to service failures in normal design (ballistic design in an admitted exception) that could have been prevented by increasing the notched impact strength of the part to much over 10 or 15 ft-lb. at the working temperature.

From the practical standpoint the only property that changed materially with hardenability (in the tests detailed in this paper) was the ratio between yield and tensile strength; it decreased appreciably as the hardenability and quenched hardness decreased. To obtain approximately the same ratio in the center of a 4-in. section as in a 1-in. section it is necessary to specify a deep hardening steel similar to Type 9530 (Fig. 6).

Since there has recently been much more interest in resistance to brittle failures, rather than maximum yield-to-tensile ratios, the question arises, "What type of cast steel microstructures are associated with unacceptable notched impact strengths?" None of the liquid quenched cast steels showed unacceptable notched impact strengths; Charpy tests after water quenching and tempering at 1200° F. were always in excess of 20 ft-lb., even in the center of 4-in. sections. Tensile strengths were as high as 145,000 psi. When the water quench was followed by a 1000° F. temper, the Charpy values exceeded 10 ft-lb. with tensile strengths of 175,000 psi. and more.

Much slower cooling rates, as in air, were required to produce notched impact strengths less than 10 ft-lb. and even then only in the center of 4-in. sections. Figure 7 at 75 × illustrates two of the more extreme examples; the caption contrasts conditions of the same two steels after water quenching and tempering.

Note that the tensile elongation and reduction of area of these normalized (air cooled) cast steels give no indication of notch brittleness. It would have been simpler if *all* of these high hardenability steels had been low in the Charpy test after normalizing and tempering. The situation is, however, complicated by facts such as contained

in Fig. 8, for two other heats of similar analysis. At first glance it would seem that microstructure *does* play a decisive role in sections thicker than 2 in., for the structures in Fig. 8 are much more uniform than those in Fig. 7, but this is disproven immediately by the structure of the cast steel illustrated in Fig. 9.

These examples of normalized and tempered cast steels are representative of all the steels studied. In none was any correlation found between microstructure and resistance to brittle fracture as measured by tensile ductility or notched impact strength. The inherently coarse-grained, silicon killed steels are prone to show more free ferrite, grossly segregated, but almost invariably they had slightly higher mechanical

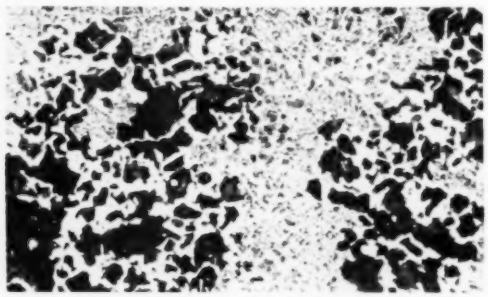

Fig. 9 — Normalized Casting (4-In. Section) With Excellent Toughness Despite Free Ferrite in Nonuniform Distribution. Type 9430, air cooled, drawn at 1200° F. Basic electric steel. Tensile 98,000 psi., elongation 22%, reduction 40%, Charpy test, 27 ft-lb. at 75° F. 100×

properties than the inherently fine-grained, aluminum killed steels with more uniform microstructures.

Perhaps the difference in tensile ductility and notched impact strength due to relatively large differences in cooling rate is not a question of specific microstructure, but of microstructural *uniformity*. This is certainly true for cast steels (and probably for wrought). Timmons[2] has shown that the increase in mechanical properties due to liquid quenching over air quenching or annealing is due to a more uniform hardness of the microconstituents. Slow cooling allows greater time for segregation and better development of the various micro areas.

The standard etchants outline the microconstituents but give no information as to their properties and relative hardnesses. Therefore, appearance alone cannot predict the mechanical properties of cast steel.

Assurance of Tough Steels

How can one be assured against low resistance to stress concentration and brittle fracture in heavy sections of cast steel?

First, by control of heat treatment. A quenching rate in excess of about 6° F. per sec. at 1300° F. insures a notched impact strength in excess of 20 ft-lb., with tensile strengths up to 150,000 psi., or 10 ft-lb. or more with tensile strengths up to 175,000 psi.

At slower cooling rates hardenability of the steel does play a part, but control of brittleness should be by limiting the hardenability rather than the opposite. Even in air quenching or normalizing, hardenability is still not the whole answer. A statistical analysis by one of the authors[6] showed that (regardless of analysis, hardenability or tempering temperature) if the resultant tensile strength exceeded 110,000 psi. after normalizing and tempering, *some* keyhole Charpy values at room temperature would be less than 10 ft-lb., the frequency of low impact values increasing as the section size and hardenability increased.

Liquid quenching is the answer to acceptable resistance to stress concentration (as measured by the notched impact test at room temperature) if tensile strengths exceeding 110,000 psi. are required. Liquid quenching will double and often quadruple the notched impact strength. If 10 ft-lb. are required at subzero temperatures, a quenched structure is a *necessity*, regardless of the steel's analysis or method of manufacture.

It should again be emphasized that, while no low-temperature impact tests were made on the 2 and 4-in. sections, properties shown in this paper have demonstrated conclusively the fallacy of jumping at conclusions from just the microstructure.

In conclusion, it has been shown that minimum hardenability specifications and uniform microstructure insure no mechanical properties except ratio of yield to tensile strength. If this is specified for heavy sections to be more than 90% of that obtained in 1-in. sections, the part must be quenched out to at least 80% martensite, and the hardenability curve for the steel be almost a horizontal straight line. For resistance to brittle fracture the hardenability and amount of martensite required on quenching can be much lower. In some structures the highest yield-to-tensile ratio may be a necessity, but they are in the minority. If the whole section is not at maximum stress there is no reason to insist on maximum hardenability — in fact, all advantages are in lower hardenability to lower cost and increase foolproofness.

Critical Points

By the Editor

Observations at Hawthorne

IN THE DEVELOPMENT of the telephone from Bell's simple battery circuit with hand-cranked call bell to today's automatic dials, loaded cables and vacuum-tube controls, there has been a parallel invention and perfection of special metals and forms, each used for some necessary combination of electrical, magnetic and mechanical properties. Some of the important alloys for the multitude of parts going into telephones and central stations are of ancient origin, like brass, bronze and nickel silver; others are as new as plutonium. Even though surprisingly large quantities are required to make a million tiny parts, the unusually close limits of purity, surface condition and size required for long life and reliable telephone service tend to remove the materials from the "commercial" category. Western Electric Co. (the manufacturing subdivision of the American Telephone and Telegraph system) has therefore found it distinctly economical to make in its own shops much of the raw material. This is especially true of alloys whose ingredients are rather costly and whose scrap should be completely and quickly recovered. Such operations — supra-commercial, as it were — make a metallurgist's tour of the tremendous Hawthorne plant on Chicago's outskirts a noteworthy occasion. Further interest, as if for good measure, is in unique items used in rather small poundage and wanted (as yet) in none other than the communications industry.

Take, for example, an improved Permalloy* (to be used in radar, an amazing but by no means unexpected extension of Bell Laboratories' researches on communication by directional radio), melted and cast in vacuum, hot rolled from baby ingot into strip, surface prepared with utmost care, cold rolled almost to foil thickness uniform to the limits of a flying micrometer, annealed in hydrogen, coiled by the half-mile with uniform tension while immersed in a milky slurry of insulating oxide. For another example, where else would you see a machine for tinning a narrow edge of nickel silver strip, so that contact fingers punched therefrom will be ready-made for soldered connections? Or a caged department using a million dollars worth of palladium every year for contact points?

This palladium matter is especially interesting. Palladium is just about the best metal there is for make-and-break contacts; it is hard enough so it doesn't batter out of shape in normal operation; it has low electrical and contact resistance; it does not react and build up surface barriers with oxygen, moisture, sulphur and other constituents of industrial atmospheres, even when heated by the electric currents. But it is so expensive, like platinum, that it must be used most parsimoniously — just tiny tips on nickel nubbins that in turn are fixed to the ends of sharp operating fingers or springs. So the metal specialists at Hawthorne start off with palladium wire (0.008 in.) and roll it into a half-moon section. Also a considerably larger nickel wire (0.024 in.) is rolled into a shape like the silhouette of Miles Standish's hat. These two shapes (each so small that it is best seen under a 15× binocular microscope) are then welded together, flat to flat-top, between copper electrode rollers. Finally the bottom of the composite (the brim of the Standish hat) forms a welding surface for continuous attachment down the center of a brass strip from which the parts are then cut on a punch press. Precious palladium is reclaimed from punch-press scrap and inspection rejects by cutting off the bulk of the common metal, dissolving the rest in acid, filtering and washing the insoluble palladium fragments, melting them into a small ingot under an oxy-acetylene torch, swaging and drawing into cobweb wire, and starting out all over again.

*Registered trade name, Western Electric's Patent Dept. would have us emphasize.

A Scientists' Reserve

MADE a flying visit to South Norwalk, in Connecticut, where Remington-Rand, Inc., has recently opened a model laboratory devoted to advanced research, presided over by Lt-Gen. Leslie R. Groves, retired wartime director of the atomic-bomb program. Remington-Rand's manufacturing operations are exceedingly diverse and scattered, and research problems that are common to stationery and typewriters, bookcases and bookkeeping machines might almost seem nonexistent, except that much office machinery is susceptible to electrical operation and electronic control, and is made of metal. . . . The General, who is swamped with invitations to speak on the topic of atomic

energy, is fortunately able to express his opinions vigorously and in words that stimulate either agreement or disagreement. We had no difficulty in disagreeing on certain things, nor trouble in agreeing on the proposition that any graduate student who accepts a scholarship from Uncle Sam should swear an oath of allegiance to the United States and, also, join a "Scientists' Reserve", agreeing to spend an appropriate term in governmental service if, as, and when his services are needed. . . . Paul Strubhar, presiding over a well-equipped metallurgical department, is currently studying materials of construction. For example — a standard cast iron part has numerous slots machined into it, wherein hardened levers slide. Minor wear, due to side slap, is resisted apparently by the free graphite in the microstructure — no lubrication being permissible. Can such a part, expensive to machine, be replaced by a die casting? Zinc-base die castings wear unduly. (Strangely enough, the scruff is low in zinc oxide and very high in the oxides of the alloying elements.) Furthermore, size tolerances, and especially surface smoothness within the narrow slots, are right at the limits of a die casting's possibilities. An accurate enough part might be cast in aluminum and a surface oxidized to furnish the wear resistance; on the other hand, this might merely shift the wear to the levers. Alternatively, an accurately folded stamping of thin sheet steel might be cast in.

Accurate Gages and Sharp Cutters

REVISITING Pratt & Whitney's operations with Past President d'Arcambal, found a fine new factory in the verdant outskirts of Hartford ("new" in the conservative New England sense of anything less than 10 years old), and was reminded of an article on their methods of manufacturing gage blocks, published when *Metal Progress* was a bare six months old. Here, now, is a room 440 ft. long, maintained at constant temperature and humidity, wherein final lapping operations bring the blocks to size and flatness incomprehensibly accurate — four millionths of an inch. On doubting the commercial need of such precision in metal manufacture, was reminded that ball bearings have almost achieved it already, and that tolerances on interchangeable machine parts are continually decreasing. Likewise the user must be confident that several blocks "wrung" together to build up a definite dimension must contain no cumulative errors. . . . In that old article in *Metal Progress* the methods for insuring dimensional stability in these gage blocks were concealed in the words "special seasoning treatment". The steel contains 1.15% carbon, and a little chromium; after quenching and even after prompt refrigerating it retains some austenite. This austenite may transform (and expand) slowly with time at variable room temperatures. However, it is stabilized (not transformed, but cured of any great desire to transform) by tempering at correctly chosen temperatures, as demonstrated clearly by Prof. Morris Cohen in recent studies at Massachusetts Institute of Technology. [ANTIQUARIANS' AND PATENT ATTORNEYS' NOTE: The 1931 article says: "The magnetized gage block is immersed in a bath of kerosene which contains in suspension very fine steel dust. Even the most minute cracks are then visible by steel particles that accumulate there."] . . . . In the orderly and well arranged heat treat devoted to manufacture of cutting tools, W. E. Bancroft, chief metallurgist, explained an inspection practice worked out with steel suppliers wherein a heat is labeled "P. & W. accepted" if a check ladle analysis shows it to be of proper chemical composition; for the manufacture of small tools of high speed steel he finds it best to keep the carbon and vanadium within narrow limits. Even though the complete heat were not shipped, the remainder could be rolled and warehoused and future consignments made from it. Every lot of small tools in process is accompanied by a card giving detailed hardening instructions and desired hardness. . . . While several types of toolsteels are used, 18-4-1 high speed is still the favorite. "Nitrided" tools (cyanide salt bath process) are furnished at no extra cost, nitrided taps with ground flutes being a "natural" for machining cast iron. Hard chromium plating is economical for special services, even at extra first cost. d'Arcambal also exhibited some tiny taps and reamers made of cemented tungsten carbide — most extraordinary to contemplate. "They never wear out," he complained. "Fortunately for the resale business, they are brittle and sometimes break!"

Addition and Correction

THE original manuscript of the article "Resistance of a Gun Steel to Explosive Impact" by F. Poboril in July *Metal Progress* (p. 59) was contracted about 50% before publication. In this condensation, there was an unfortunate omission of credit. Dr. Poboril's manuscript was a summary of an article written jointly with V. Koselev (see also *Iron and Steel*, June and July, 1948). The work described was not done at the Vitkovice Steelworks, as inferred by the second paragraph of the article in *Metal Progress*.

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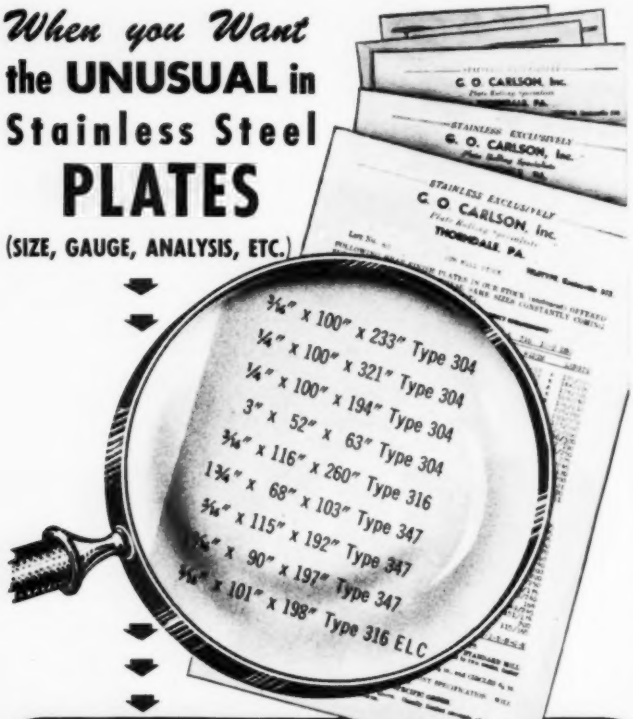
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Personals

Carpenter Steel Co., Reading, Pa., announces that **Avard W. Taylor** has been appointed district manager of the Philadelphia and Reading territories. Mr. Taylor was previously an assistant manager.

Loren W. McOmber has been transferred by Du Pont to its Philadelphia office as technical representative in the metal treatment field for eastern Pennsylvania, New Jersey, Maryland and Virginia.

Jack Mervis, formerly process engineer at the Duquesne works of the Carnegie-Illinois Steel Corp., is now metallurgist for the openhearth and rolling mills of the Torrance, Calif., works of the Columbia Steel Co.

Robert G. Wheeler is now a physical metallurgist at the Hanford works of the General Electric Co.

Thomas J. Janus has recently been appointed junior metallurgist at the Standard Steel Works Div. of Baldwin Locomotive Works, Burnham, Pa.

Francis H. Laxar has resigned as instructor in engineering at West Virginia Institute of Technology to become instructor in metallurgy at Lehigh University, Bethlehem, Pa.

Jack H. Wernick has been appointed instructor in metallurgy at the Pennsylvania State College, State College, Pa.

Kaiser Steel Corp., Oakland, Calif., announces the appointment of **J. M. Cosgrove** as Northwest district sales manager. Mr. Cosgrove, who was formerly district sales representative for the company, has his headquarters at Seattle.

A. L. Petersen, former manager of Joseph T. Ryerson & Son, Inc.'s, St. Louis, Mo., plant has been transferred to manage the Pittsburgh plant. Mr. Petersen has been with Ryerson since 1913, and has worked in its Chicago, Detroit and St. Louis plants. **John M. Acee**, former manager of sales at Ryerson's St. Louis plant, will succeed Mr. Petersen as manager.

Charles D. Townsend is now an executive engineer, Associated Engineers, Inc., Fort Wayne, Ind.

After receiving his D.Sc. from Carnegie Institute of Technology in June 1949, **R. Wayne Parcel** has been appointed metallurgist in the technical department of Remington Arms Co., Inc., Bridgeport, Conn.

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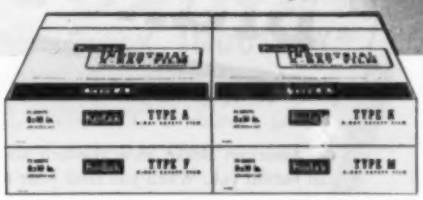

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Personals

Precision Metalsmiths, Inc., Cleveland, announce that **Leonard G. Daniels** ⊖, a June 1949 graduate of Case Institute of Technology, will head its newly created engineering-design department.

Bernard J. Egan ⊖ has been transferred by Revere Copper & Brass, Inc., from the technical sales department of the Rome, N. Y., division to Seattle district manager for the Pacific Northwest.

John M. Thomas ⊖, formerly research associate in the Engineering Research Institute of the University of Michigan, has joined the engineering department of Hoskins Mfg. Co., Detroit, as a metallurgical engineer.

William T. Moore ⊖ is a metallurgical trainee at the McCook plant, Brookfield, Ill., of Reynolds Metals Co.

Scully-Jones & Co., Chicago, announce the appointment of **A. A. Gustafson** ⊖ as its factory representative in the State of Minnesota and part of Wisconsin.

Harry R. Dahlberg ⊖, former assistant professor of industrial engineering at Oregon State College, has recently joined Twin City Testing and Engineering Laboratory, St. Paul, Minn., as metallurgical engineer.

C. Robert Lillie ⊖ is now technical aide to the Committee on Ship Steel, National Research Council, Washington, D. C.

After completing his course at the University of Alabama, **E. F. Lawrence** ⊖ has returned to the Anaconda Copper Mining Co., Butte, Mont., where he will be research geologist.

Hugh P. Gibbons ⊖ received his B.S.E. from University of Michigan in June 1949 and has been appointed assistant superintendent of the Hillsdale Foundry Co., Inc., Hillsdale, Mich.

After completing work in mechanical technology at Utica Tech, **Max Linza, Jr.,** ⊖ is now employed by the College of Applied Science of Syracuse University as a metallurgical laboratory technician.

James P. Blackledge ⊖, who received his M.S. at the University of Utah in June 1949, has accepted a position as staff research engineer with the Industrial Research Institute, University of Denver.

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Personals

A. F. Holden Co., New Haven, Conn., announces that the following men have been promoted from field engineers to district managers: **C. R. Brown** ⊖, New Haven, Conn., **R. B. Durfee** ⊖, Skaneateles, N. Y., **C. R. Hecker** ⊖, Plainfield, N. J., **H. A. Moffat** ⊖, Lakewood, Ohio, and **J. P. Shotland** ⊖, New York City.

Leland W. Browne ⊖, formerly president of the Darby Corp., Kansas City, Kan., is now president of the Gate City Steel Works, Omaha, Neb.

Jerome W. Kaufman ⊖, previously with the Philadelphia Ordnance District and recently graduated from Lehigh University, is now employed as metallurgist with the Naval Air Development Station at Johnsville, Pa.

William M. Lehrer ⊖, formerly chemistry instructor at Rensselaer Polytechnic Institute, has joined the staff of the metallurgy division of Argonne National Laboratory, Chicago, as a junior metallurgist.

Youngstown Sheet and Tube Co., Youngstown, Ohio, announces that **John E. Stukel, Jr.,** ⊖ has joined the operating department as a development engineer. Dr. Stukel was formerly assistant professor at Carnegie Institute of Technology.

C. Alan Lindquist, Jr., ⊖, previously at the electronic shop of Western Electric, Inc., is now with the Electrical Reactance Corp., Franklinville, N. Y., as ceramic engineer.

S. G. Taylor Chain Co., Hammond, Ind., announces the promotion of **E. W. Chapman** ⊖ to the position of assistant sales manager. Mr. Chapman has been with the company for 16 years.

William R. Huff ⊖, formerly chemical engineer with the Public Service Co. of Indiana, Inc., is now chemical engineer with the research pilot plant of the synthesis gas production laboratories at the Morgantown, W. Va., station of the U. S. Bureau of Mines.

James Taylor ⊖ has recently been appointed metallurgical engineer of the American Locomotive Co., Schenectady, N. Y.

W. T. Sweeny ⊖, formerly research associate with the University of Michigan, has accepted a position as physicist at the National Bureau of Standards, Washington, D. C., where he will perform research on dental materials.

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Personals

George A. Bivens is now with the Worthington Pump & Machinery Corp. as a student trainee in the research and development department of the Harrison, N. J., works.

John R. Small is now with the Naval Ordnance Test Station, China Lake, Calif., as metallurgist in charge of installation and operation of the foundry.

James Mericka, Jr., is now vice-president of the Diamond Heat Treating Corp., Detroit.

H. A. Armstrong, who graduated from Colorado School of Mines in July 1949, is now a junior metallurgist at the Colorado Fuel & Iron Corp., Pueblo, Colo.

Theodore B. Focke is now general manager and vice-president of Wright Aeronautical Corp., Wood Ridge, N. J.

Harold G. Bowen, Jr.,, who has been in Turkey advising the Turkish Navy as training and ordnance officer of the Naval group of the American Mission for Aid to Turkey, has returned to Newport, R. I., and is enrolled in the senior course at the Naval War College.

Ralph R. LaMotte has been appointed chief engineer of the Aeroproducts Division, General Motors Corp., Dayton, Ohio. He joined the company in 1941 as assistant chief engineer and has been acting chief engineer since the first of the year.

Robert K. Allen, a June 1949 graduate from the University of Wisconsin, is now a welding engineer in the works laboratory of the General Electric Co.'s Locomotive and Car Equipment Division in Erie, Pa. Mr. Allen was also co-author of a prize-winning paper in the Lincoln Arc Welding contest.

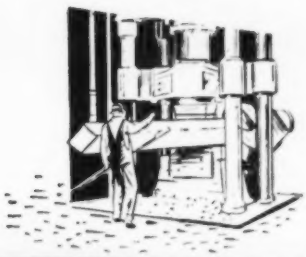
The Welding Arc*

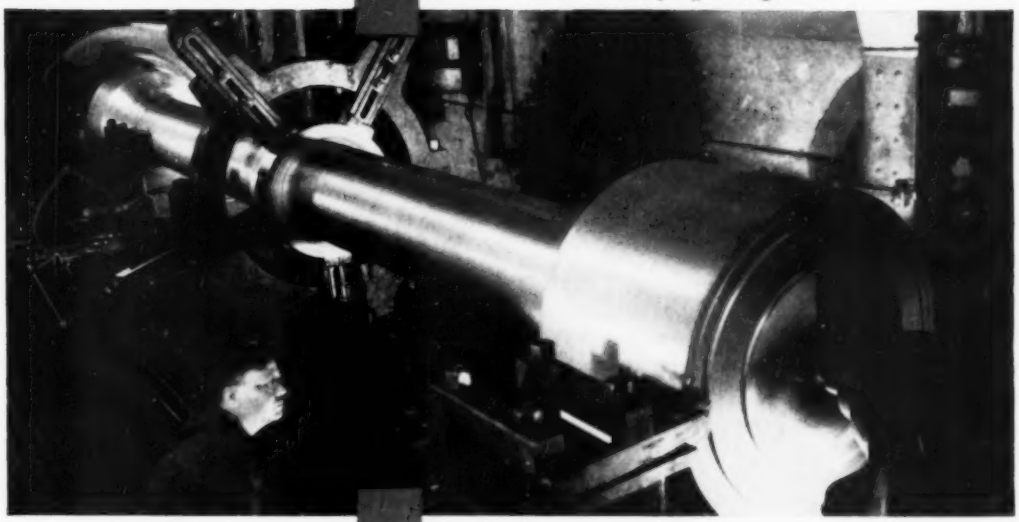
THE WELDING ARC differs from other short, high-pressure, heavy-current arcs mainly in application. The welding arc is a relatively steady-state phenomenon used to melt or transfer molten material.

(Continued on page 378)

*Abstracted from "The Nature of the [Welding] Arc", by J. D. Cobine, General Electric Research Laboratory, presented at the A.I.E.E. Conference on Electric Welding, December 1948.

FORGINGS BY FINKL





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The Welding Arc

(Starts on page 376)

and the basic phenomena are not essentially different from those occurring in the short, steady-state arcs used for illumination.

The arc is defined as a discharge having a voltage drop at the cathode of the order of the least ionization potential of the atmosphere in which it burns. For the short arc, the voltage across the entire discharge is of the same order of magnitude as that of the cathode. The high-pressure arc is characterized by high temperatures, both in the column and at the electrodes. For the purpose of this discussion the arc may be considered in three sections: the column, the cathode region and the anode region.

In the high-pressure arc, column temperatures from 4050 to 7600° K. have been measured at atmospheric pressure. It is believed that a temperature of the order of 11,000° K. may exist in the center of the arc column at currents of the order of 200 amp. A contraction of the column, due to the magnetic effect, begins at about 30 amp., resulting in a current density of the order of 3000 amp. per sq.cm. The outer zone, or mantle, is a region of chemical activity, much cooler than the core and of negligible conductivity.

The column is maintained by electrical energy given to free electrons and positive ions by the electrical gradient of the column, or plasma. The free electrons gain energy from the electric field of the arc in free flight and give up various amounts of it in collisions with atoms and molecules. Since the electron current density in an arc is quite high, some of the excited atoms will be struck by another electron and thus ionized. Positive ions resulting from ionizing collisions also gain energy from the electric field which they give up in considerable amounts to neutral particles in collision. Thus, the neutral gas in the column has its temperature raised to a high value.

The high temperature of the arc column results in the dissociation of polyatomic molecules. The resulting atoms diffuse to the walls, that is, to the electrode surface or surrounding relatively cold gas, and there give up the energy of dissociation. This results in much of the heating observed at the electrodes or at the "work" and "electrode", as expressed in welding terms.

(Continued on page 380)

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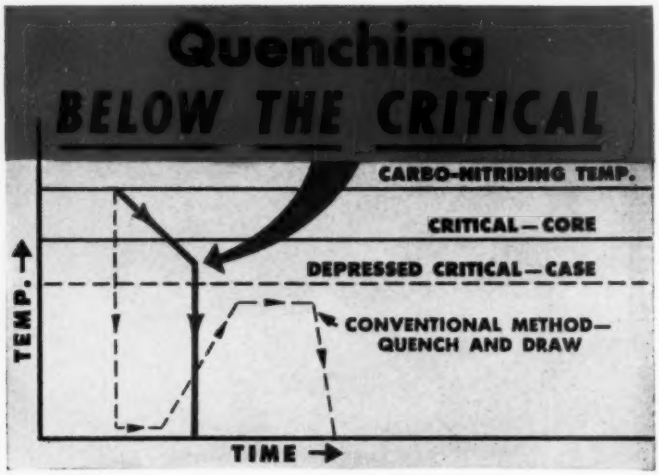

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The Welding Arc

(Starts on page 376)

At the cathode end of the column is the cathode drop region. At the electrode end of this region is the cathode spot, which is the point of current transfer from metal to gas. The high temperature of the cathode spot is produced largely by positive ion bombardment, and these ions arrive at the cathode with an energy approximately equal to the cathode drop voltage.

The cathode drop is a result of the positive ion space charge at the cathode end of the column. This space charge is produced partly by ions coming from the column but mainly by new ions produced by ionizing collisions made by electrons accelerated by the cathode drop voltage. The cathode drop is of the order of the least ionization potential of the gas atmosphere and, if the current density is high, may actually be less than this potential.

Most arc electrodes are of relatively low boiling point and are characterized by high cathode-spot current densities that are commonly quoted as ranging from 4000 to 16,000 amp. per sq.cm. Recent studies have shown that much higher values are actually realized. These measurements were made in air at atmospheric pressure by causing the cathode spot to move over the electrode surface by means of a magnetic field. The track left by the spot can then be measured by a microscope and filar eyepiece. At currents above a few amperes the tracks show a branched structure, as though the "spot" consisted of a cluster of small spots all racing wildly about. The branches appear to die out rather quickly and are replaced by others.

The appearance of the tracks suggests that the oxide is removed from the base metal of the cathode either by direct evaporation or by chemical reduction on the surface, followed by evaporation. Base metal is also removed. This action plays an important part in the welding of aluminum with the a-c. arc in the inert-gas arc welding process. The half-cycle when the work is negative provides a cleaning action.

The cathode-spot phenomenon appears to be definitely associated with the presence of oxide layers on the electrode surface. On metals of low boiling point in an inert atmosphere it has thus far been impossible to maintain a stable arc cathode unless some oxide is present.

(Continued on page 382)

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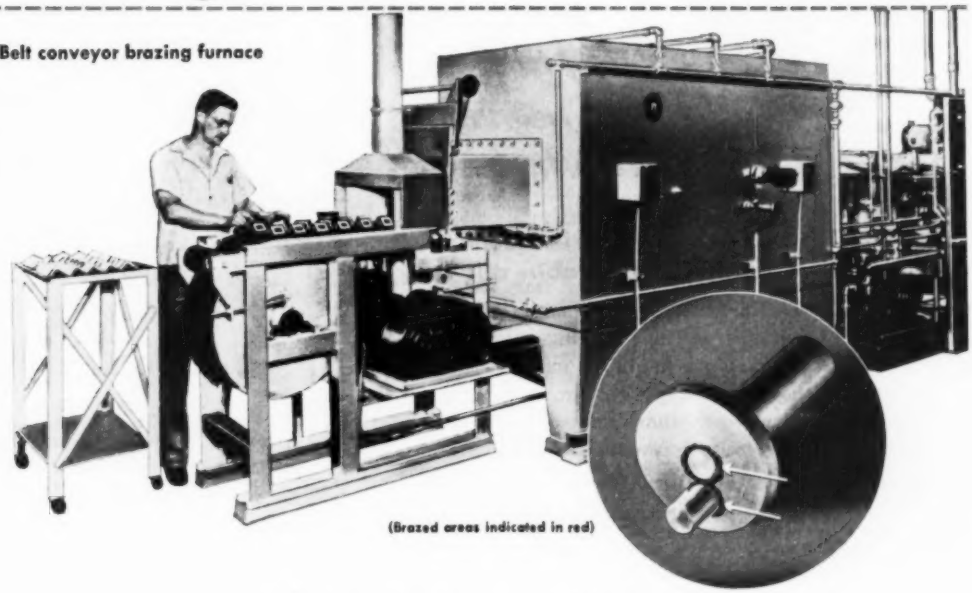

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The Welding Arc

(Starts on page 376)

The anode region of the arc may have a voltage drop of as much as the ionization potential of the gas atmosphere. Electrons reaching this zone are accelerated by the anode drop and, on striking the anode surface, give up energy equal to the anode drop plus the heat of condensation of the electrons. The anode is usually heated to a higher temperature than the cathode, which results in a greater evaporation of electrode material at the anode.

From the standpoint of gaseous discharge phenomena, the simplest welding arc is that of the inert-gas arc process in which the cathode is a tungsten electrode (straight polarity). As long as the current is held within a certain range of electrode current density, the tungsten tip will be heated sufficiently by positive ion bombardment to provide the circuit current by thermionic emission. Too low a current results in an erratic arc, while too high a current results in excessive melting of the tungsten. There being no polyatomic molecules, the anode is heated largely by electron bombardment, the inert gas serving as a shield for the arc, to exclude air.

For welding arcs in which metal is deposited from an electrode the gaseous discharge phenomena become very complex and are not well understood, particularly the cathode phenomena. The boiling temperature of pure iron is too low to provide sufficient thermionic emission even for high currents. If the electrode contains impurities or has a coating containing them, thermionic emission is possible. Most electrode coatings contain materials which affect the arc phenomena.

The method of metal transfer in a welding arc has been explained in various ways. Much metal is transferred as drops from the molten electrode. High velocity particles may contribute little to metal transfer. These high velocity streams have not been adequately explained but may be of considerable importance in the discharge mechanism. Although roughly equal amounts of energy reach the electrodes by diffusion, the cathode would tend to receive somewhat more heat of atomic dissociation from the arc column than the anode. Since the voltage drops at the two electrodes are not the same and the column voltage drop is not always negligible, the product of arc volts times amperes is only a very rough measure of welding energy.

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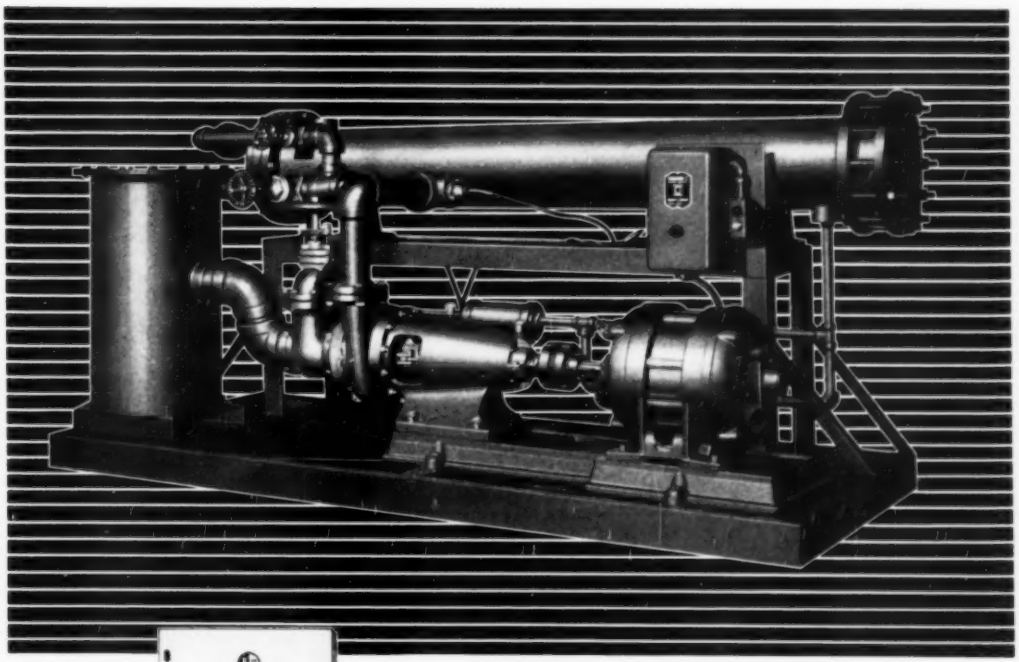

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Interesting booklet on Accumet Castings tells how these versatile castings lower your unit production costs and permit the use of materials which are difficult to forge or machine. *Crucible Steel Co. of America.*

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692. Castings, Alloy

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Bulletin DH-114 contains full information on Tukon Hardness testers for use in research and industrial testing of metallic and nonmetallic materials. Also included is bulletin DH-7, giving experiences in various fields. *Wilson Mechanical Instrument Co.*

722. Heat Treating
New bulletin now available on Series T Ipsen automatic heat treating unit for lower costs and efficient operation. *Ipsen Industries, Inc.*

723. Heat Treating
Full information available on all types of Edicurrent furnaces and Lavite salt baths for hardening, tempering, quenching, annealing, and cyaniding operations. *Bellis Heat Treating Co.*

724. Heat Treating
Attractive new booklet, "The Science of Gas Chemistry for Heat Treating", Form SC-129, gives complete details of applications for prepared gas atmosphere compositions and costs. *Surface Combustion Corp.*

725. Heat Treating
Form 7340 C, an 8-page illustrated article, contains interesting story of the conveyorized harden, quench and draw installation at American Fort Pitt Spring Division. *Sunbeam Stewart Industrial Furnace Div.*

726. Heat Treating
Pressed steel lightweight sheet alloy heat treating units furnished in any size, design or specification. Write for full information on this. *The Pressed Steel Co.*

727. Heat Treating
Barrett standard anhydrous ammonia is available in 150, 100 and 50-pound cylinders in conveniently located stock points. Free literature mailed on request. *Barrett Division, Allied Chemical & Dye Corp.*

728. Heat Treating
New 36-page booklet "Heat Treating and Pickling of Armco Stainless Steels" presents comprehensive and current information on recommended procedures, based on practical laboratory experience. *Armco Steel Corp.*

See additional listings on Page 384

729. Induction Heating
Induction heating at standard power-line frequencies on such applications as autoclaves, die noxales, stress relieving, etc. Completely described in new bulletin No. 28 just published. *Ajax Electrothermic Corp.*

730. Induction Heating
Learn the many advantages of applying Tocco induction heating for hardening, brazing, soldering, annealing or forging operations. Send for free booklet now available. *Ohio Crankshaft Co.*

731. Inspection
Descriptive literature on surest method of accurate inspection by use of the dual-frequency-type special comparator for testing both ferrous and non-ferrous metals. *Magnetic Analysis Corp.*

732. Instrument Panels
Bulletin P1-1 gives prices and specifications for cabinet-type instrument panels providing simple, efficient method for mounting recording instruments and auxiliary control equipment. *Wheelco Instruments Co.*

733. Lubricants
Two new booklets furnish interesting new facts on Silicone greases. Silicone Notes D-5 gives properties, performance and uses. D-6 contains information on how to use DC 44 grease in bearings of electric motors. *Dow Corning Corp.*

734. Machine Design
Fundamentals of producing low-cost machine parts — design, material and treatment — are discussed in new 72-page "Three Keys to Satisfaction". *Climax Molybdenum Co.*

735. Machine Parts
Illustrated Nitralloy data booklet lists many advantages of nitrided nitralloy for corrosion-resistant, surface-hardened machine parts. *Nitralloy Corp.*

736. Metal Coatings
Explanation of high-vacuum evaporation of metals and other solids set forth in detail in new 12-page booklet "Vaporized Metal-Coatings by High Vacuum". *Distillation Products, Inc.*

737. Microhardness Tester
Descriptive leaflet on MH microhardness indenter, a new instrument for measuring hardness of microconstituents, fine wire, metallic foils, electrodeposited coatings, etc. Adaptable to table microscopes, simple to operate and low in cost. *Erb & Gray.*

738. Microscope
New 36-page brochure dealing with the Vickers projection microscope will be sent on request. *R. Y. Ferner Co.*

739. Microscopes
Two new catalogs are now ready for mailing: M78 on metallurgical microscopes and M157 on stereoscopic microscopes. *American Optical Co.*

740. Microscopes
New catalog D-104 contains a full description of the phase contrast principle, with an article on proven uses, plus actual photographs taken with these accessories. *Bausch & Lomb Optical Co.*

741. Nickel Alloys
Improve structure and machinability of your gray iron castings and reduce machining time, tool wear, rejections, by using small ladle additions of Niniloy, described in new booklet. *International Nickel Co.*

742. Oils, Quenching
Catalog V-1146 gives detailed information on self-contained oil coolers, together with easy selection tables. *Bell & Gossett.*

743. Oils, Quenching
Interesting 12-page booklet on B-2, new type of quenching oil specially developed for greater hardness in carbon steels with less distortion and lower costs. *Rodman Chemical Co.*

744. Oils, Quenching
Interesting booklet describes many advantages of various quenching oils developed for uniform hardness in heat treating, higher viscosity where oil remains abnormally hot, and longer service life. *Sun Oil Co.*

745. Ovens
"Why", No. 397R, a new manual, presents a comprehensive discussion of Precision-Freas ovens. Full information on incubators, ovens and sterilizers is included. *Precision Scientific Co.*

746. Pack-Hardening and Isolating Pastes
An attractive bulletin describes Carburit, the perfect solution to selective hardening problems, requiring no furnace. Also described is the new easy-to-use isolating paste, Isopac, that keeps desired sections soft when hardening in box, salt bath or other methods. *Deuss Chemical Labs.*

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

747. Photomicrographic Cameras

Descriptive bulletin on Gamma micro cameras for use with biological, polarizing or metallurgical microscope, and providing complete interchangeability of all parts. *Gamma Instrument Co., Inc.*

748. Plating

Smooth plating and advantages of Unichrome Copper are discussed in informative bulletin. *United Chromium, Inc.*

749. Polishing

New booklet "Polishing Cloth and Abrasives" furnishes first-hand description and classification of some of the most used but least described accessories in modern sample preparation. *Buehler, Ltd.*

750. Polishing Machinery

Catalog 60 illustrates complete line of polishing, buffing, grinding and deburring machinery. *Hammond Machinery Builders, Inc.*

751. Powder Metals

Attractive new booklet on Fastell for heavy duty electrical contacts is a valuable contribution to metallurgical literature. *Fansteel Metallurgical Corp.*

752. Presses

Bulletin 4902 introduces a short cut in straightening of large weldments, structural shapes, forgings, castings, and plates. The new H-P-M, a two-way all-hydraulic press, handles operations without moving the part, thus saving time — up to 15 hours in one instance. *Hydraulic Press Mfg. Co.*

753. Presses

Valuable reference catalog 949 contains 60 pages of important information on pressure vessels, styles and types and other handbook material. Sent upon request on company letterhead. *Lenape Hydraulic Pressing & Forging Co.*

754. Pyrolance

New bulletin 1724-D includes photos, complete description and prices of the Pyrolance for temperature readings of molten metal in nonferrous foundries. *Illinois Testing Laboratories, Inc.*

755. Refractories

Bulletin HC-103T describes Hearth-Crete, a new, improved chrome magnesite castable refractory for forge and heating furnaces, basic open hearth, boiler and slag tap furnaces. *Quigley Co.*

756. Saw, Cutting

Folder with complete details of new model M metal-cutting band saw, the first of a series of machines and equipment to be manufactured by this firm. *W. F. Wells & Sons.*

757. Sawing Machines

"Manufacturing with Continuous Sawing Machines" is the title of a new 224-page encyclopedia showing amazing variety of uses of the Contour Saw to cut every kind of material. Sent free to industrial executives. *DoAll Co.*

758. Saws

Complete blade service for metal sawing is described in Marvel Saw Blade catalog. *Armstrong-Blum Mfg. Co.*

759. Sodium Cyanide Waste Disposal

New technical literature describes safe, easy method of cyanide disposal in heat treating and plating departments to prevent stream pollution. *A. F. Holden Co.*

760. Solders

Bulletin 45 gives full information on low-temperature silver solders. Samples sent on request. *American Platinum Works.*

761. Spectrographs

Grating spectrographs, in both the one-meter and three-meter styles, outlined in detail in new 12-page bulletin No. 32. *Baird Associates, Inc.*

762. Speed Alloy

Speed alloy plates are stocked in widths up to 72", allowing wide range of use—from zinc die-casting dies to machined parts. Fully described in bulletin 905. *W. J. Holliday & Co.*

763. Steels, Alloy

Supplement manual to 50th Anniversary book now available on chromium molybdenum steels, giving chemical and physical properties on cold finished bar steels. *Bliss & Laughlin, Inc.*

764. Steels, Alloy

New book is now available on the selection of the proper alloy steel grades for each manufacturer's needs. Write for free copy of "Wheelock, Lovejoy. Data Book". *Wheelock, Lovejoy & Co.*

765. Steels, Alloy

Hardenability charts now available for many standard alloy-steel grades will help you to order steels with the proper hardness qualities. *Bethlehem Steel Co.*

766. Steels, Low Alloy

You can have one-third more production through the use of Hi-Steel, which has nearly twice the working strength of ordinary steels plus the ability to stand up under impact loads. Send for free booklet. *Inland Steel Co.*

767. Steels, Stainless

Weekly lists with analyses of all plates in stock will keep you regularly informed on latest data. *G. O. Carlson, Inc.*

768. Steels, Stainless

Full information, including prices, is available on advantages of free-machining Enduro stainless steel. *Republic Steel Corp.*

769. Strain Gages

Bulletin 302 furnishes complete information on newly developed Hunter Spring Tester designed especially for precision testing of springs and spring assemblies. *Baldwin Locomotive Works.*

770. Tensile Tester

Literature is available on Model PO-40, a new portable tensile testing machine particularly adapted for field tests such as pipe welds and others where on-the-job testing is preferable. *Steel City Testing Machines, Inc.*

771. Testing

Production-line testing of motors, transformers and generators is speeded up by use of new G-E winding-insulation tester. Described in bulletin GEC-321. *General Electric Co.*

772. Testing

Bulletin 37 describes dependable qualities of Electromatic testing machines equipped with electronic high magnification recorder. *Tinius Olsen Testing Machine Co.*

773. Thermocouples

Complete data on Engelhard reclaiming process show how to save up to 74% with one long platinum thermocouple, compared with the cost of a new unit. Also new bulletin 330-D describes a wide range of thermocouples and accessories. *Charles Engelhard, Inc.*

774. Thermocouples

Catalog 59-R tells complete story about use of Chromel-Alumel couples and extension leads. *Hoskins Mfg. Co.*

775. Thermometers

Catalog 1100 lists complete line of TAG thermometers and hydrometers with useful Fahrenheit-Centigrade conversion tables. *C. J. Tagliabue Corp.*

776. Tool Steels

Write for new 176-page handbook, "The Tool Steels of Allegheny Ludlum", covering all the leading types and grades of tool steels. *Allegheny Ludlum Steel Corp.*

777. Tubes, Bars, Steel

New stock list now available on 52100 tubing and bars includes specifications on forgings, chrome steel bars and chrome steel tubing. *Peterson Steels, Inc.*

778. Tubing

New 24-page manual contains useful data on stainless steel tubular products, including physical properties, fabricating data, corrosion resistance, etc. *Peter A. Frasse & Co., Inc.*

779. Turbines

Information on all types of turbo compressors for heat treating, cooling, foundry, and blowing operations. Send for each bulletin by number for particular application. *Spencer Turbine Co.*

780. Vacuum Pumps

Engineering bulletin 10A describes the Cenco-Hypervac 25. A fast, high-vacuum pump for use with diffusion pumps without an intermediate booster. *Central Scientific Co.*

781. Vacuum Pumps

"Stokes Microvac Pumps for High Vacuum", new 36-page, three-color catalog and data book, includes complete line of pumps, with charts, graphs and tables for ready reference. *F. J. Stokes Machine Co.*

782. Waste Control

Bulletin ND44-96-708 contains numerous illustrations explaining in simple terms the benefits of Micromax pH control in "Effective Neutralization of Industrial Wastes". *Leeds & Northrup Co.*

783. Welding

Announcing a new welding accessories catalog containing 15 pages illustrated in two colors and covering both oxyacetylene and electric-arc welding accessories. *Air Reduction Sales Co.*

784. Welding, Arc

Descriptive data on M & T welding machines to be combined with select "70" electrodes for top-notch arc welding. *Metal & Thermit Corp.*

785. Welding Bronze

How to save material by bronze welding, an ideal combination for repair welding, building up worn surfaces and production welding, described in new 17th edition of B-13. *American Brass Co.*

786. X-Ray Unit

Catalog SB 304/4 describes new X-ray diffraction unit for foolproof operations in laboratory research. *Jarrell-Ash Co.*

See additional listings on Page 384

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METAL PROGRESS

7301 Euclid Avenue, Cleveland 3, Ohio

September, 1949

673	693	713	733	753	773
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690	710	730	750	770	
691	711	731	751	771	
692	712	732	752	772	

Please have literature circled at the left sent to me.

Name _____ **Title** _____

Company _____

Products Manufactured _____

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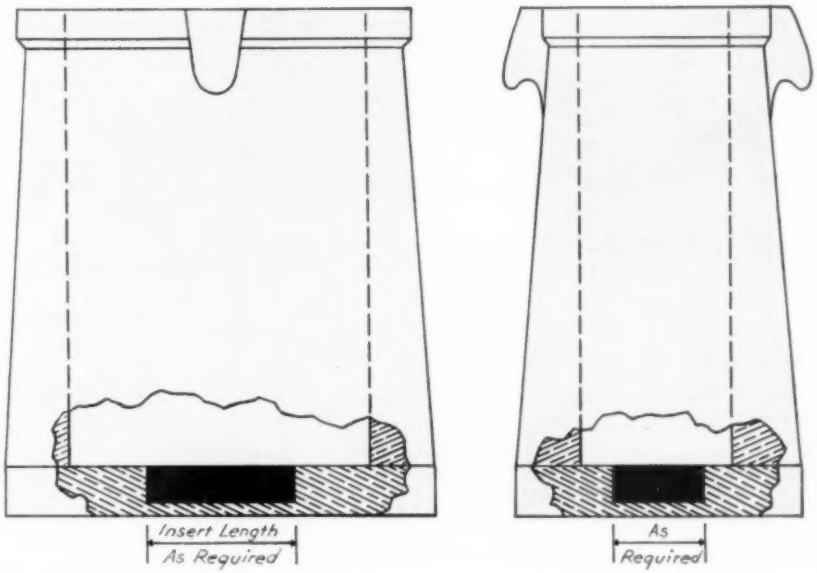
City and State _____

Postcard must be mailed prior to December 1, 1949—
Students should write direct to manufacturers.

NO MORE STICKERS!

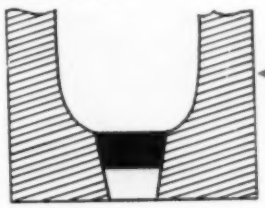
...when you use "NATIONAL" graphite stool inserts!



Use "National" graphite stool inserts in your open-bottom molds and you *eliminate stickers completely and forever!* Other advantages of graphite stool inserts are:

- They increase stool life by a wide margin
- Fewer stools are required – lower foundry costs
- They resist erosive action of falling molten metal

For more information on "National" graphite stool inserts, write to National Carbon Company, Inc., Dept. M, P.



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If you use plug-bottom molds, "National" carbon mold plugs save dollars. They last longer . . . weigh less . . . are truer to shape . . . won't stick, spall, or contaminate the ingot. Write us for complete details.

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THE CENCO-HYPERVAC 25

High temperature melting or sintering of metals and alloys requires dependable and fast high vacuum. The Cenco-Hypervac 25 Pump performs dependably with extremely fast pumping speed at low (high vacuum) pressure. It combines in a single mechanical unit ability to pump at a speed of 264 liters per minute of free air or 120 liters per minute at 1 micron and attains an ultimate pressure well below 0.1 micron. Here is a pump that will back up diffusion pumps without an intermediate booster.

Write Dept. B. V. for prices and descriptive engineering Bulletin No. 10A.

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Cathode Nickel

(Continued from p. 360)

were identical in the vertical and horizontal directions of the cathodes.

The electrical resistivity changed very little; the annealed bars that lost their hydrogen were slightly more resistant — 8.05 microhm-cm., instead of 7.98.

I believe that the hardening of nickel by hydrogen depends on the formation of a definite compound. If nickel cathodes of different hardnesses were examined by X-rays and by electron microscopy, hydrides might be detected.

Cathode nickel is not used as such, but must be remelted; however, these characteristics of hydrogen-containing nickel may be important in connection with nickel electroplates on iron or copper. I made these experiments in 1935 on my own initiative, and I present the above data so they won't be lost completely.

M. G. CORSON
Consulting Metallurgist

Some Properties of Uranium*

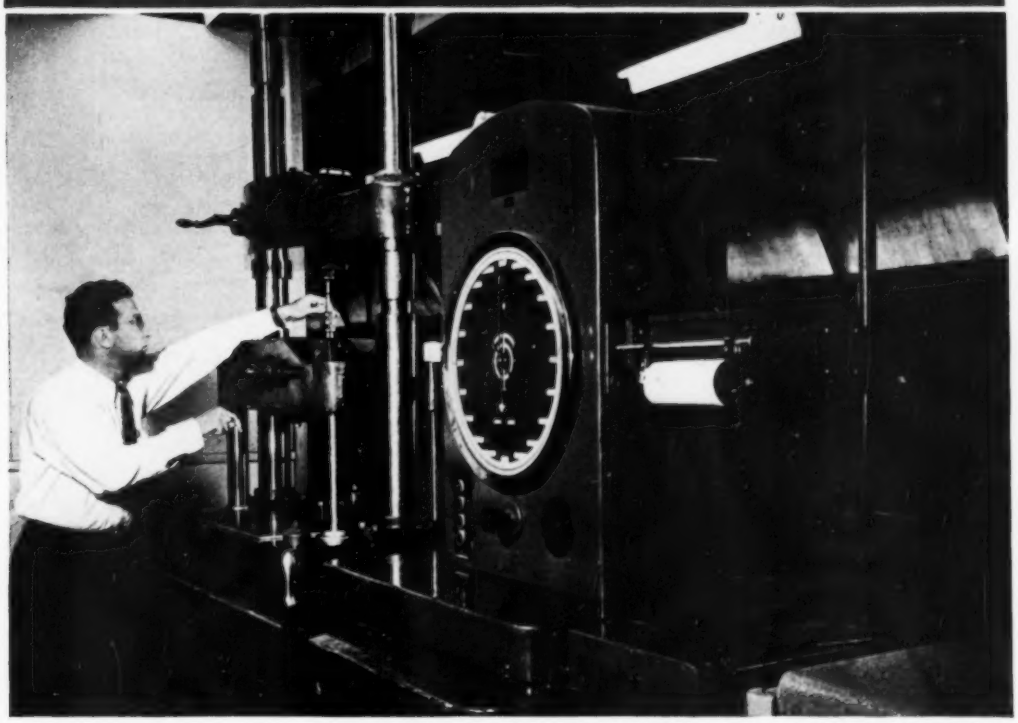
THE ELEMENTS that are of interest in connection with nuclear reactors are uranium, beryllium, thorium, and plutonium. The usual reduction of oxide by carbon does not work for these elements because the heats of formation of their oxides are extremely high. For example, half of the heat of formation of uranium oxide is 128 kg-cal. per mole. On the other hand, half of the heat of formation of CO_2 is only 47, and one third of Fe_2O_3 is only 64. Thus, carbon, magnesium, or calcium cannot be used very effectively to reduce the oxides. Uranium and the rest of these elements are so reactive they cannot be obtained by electrolytic methods.

Heats of formation of halogen compounds are more favorable, and uranium fluoride can be reduced with metallic magnesium or calcium. The fluoride is sealed together with magnesium in a heavy bomb; the

(Continued on p. 390)

*Extracts, slightly condensed, from Chapter 15 by A. R. Kaufmann, entitled "Pile Materials: Metals, Alloys and Compounds", in the book "The Science and Engineering of Nuclear Power" published by Addison-Wesley Press, Inc., Cambridge, Mass.

demands of LABORATORY RESEARCH *Are Satisfied* with an OLSEN ELECTRO-MECHANICAL UNIVERSAL TESTING MACHINE



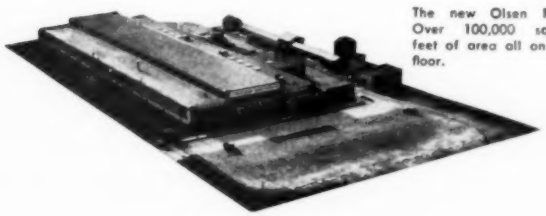
Olsen Electro-Mechanical Universal Testing Machine equipped with Electronic High Magnification Recorder. U. S. Navy, Point Loma, California. OFFICIAL PHOTOGRAPH U.S. NAVY

Extreme accuracy, performance dependability and simplicity of operation combine in the Olsen Electro-Mechanical Universal Testing Machine to give authoritative laboratory and production tests. Equipped with the Olsen Electronic High Magnification Recorder precise stress-strain curves can be plotted successfully.

The Pendulever Weighing System of the Olsen Universal, by its complete freedom from complicated operation, assures low maintenance costs while giving the highest standards of tests.

You are invited to write for full information or send today for these comprehensive Bulletins—

- ★ Bulletin 30 — Universal Testing Machines
- ★ Bulletin 36 — Testing Machines for Plastics
- ★ Bulletin 37 — Electromatic Testing Machines
- ★ Bulletin 39 — Ductility Testing Machines



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TINIUS OLSEN

Testing & Balancing Machines

TINIUS OLSEN TESTING MACHINE CO.

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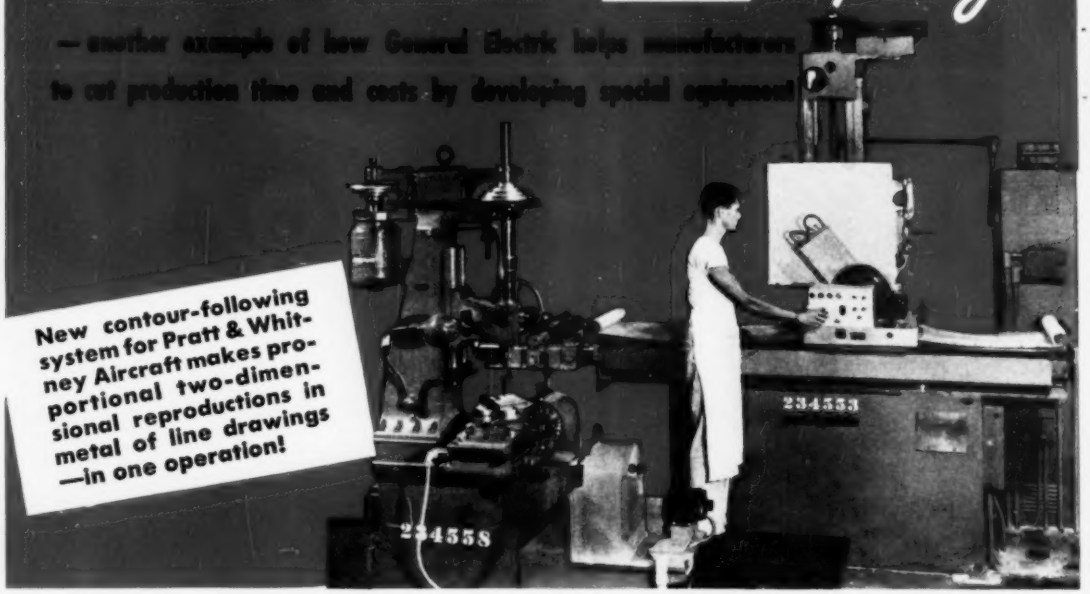
NEEDED . . equipment for "Metaltelepathy"

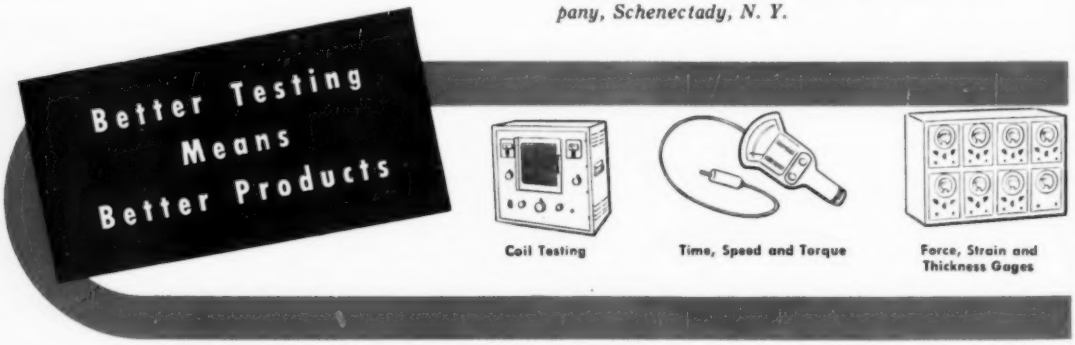
— another example of how General Electric helps manufacturers to cut production time and costs by developing special equipment


New contour-following system for Pratt & Whitney Aircraft makes proportional two-dimensional reproductions in metal of line drawings —in one operation!
234558
234553

When seeking a way to make two-dimensional reproductions in metal of line drawings, which would speed up the production of air-foil metal master patterns, engineers at Pratt & Whitney Aircraft called in General Electric. Working closely with Pratt & Whitney Aircraft engineers, G-E designers developed a new type of contour-following system. Cost of this equipment is justified for this special application because the system cuts the cost of producing a new metal master pattern by about 75 per cent and reduces production time by about 80 per cent. Although not applicable to conventional production, the equipment gives Pratt & Whitney Aircraft a valuable new tool.

A G-E Instrument for Your Problem

You may find that G-E engineers can help you by recommending one of the many stock G-E devices and instruments. Your problem, especially if it is one common to industry, may even justify developing new equipment. Write today for help to *Apparatus Department, General Electric Company, Schenectady, N. Y.*



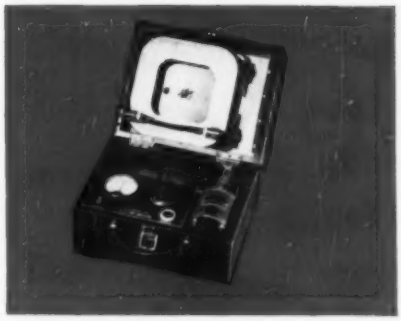
THERE ARE G-E TESTING AND MEASURING EQUIPMENTS FOR NEARLY EVERY INDUSTRIAL PROCESS

To Cut Costs of Manufacturing or Servicing Rotating Machines

—use the G-E portable dynamic balancer

By using the G-E portable dynamic balancer to balance rotors in their own bearings, you can drastically reduce the time and cost of balancing rotors in generators, motors, and in other rotating machines. The balancer is easy to use and saves time. One operator alone can balance two-bearing machines, and he needs to make only three runs.

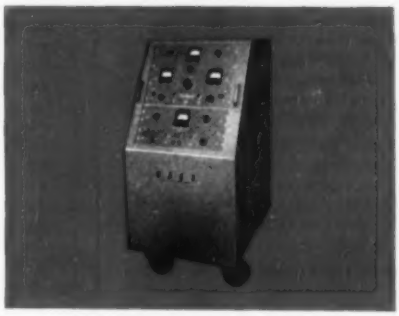
Ideal for factory-testing rotating machines, the balancer is portable. You can use it for installation or maintenance work, and for field service on any rotor within a speed range of 600 to 6000 rpm and weighing more than 30 pounds. Write for GEA-320.



To Locate Leaks in Closed Systems

—use the G-E Type M Leak Detector

By locating even the smallest leaks while your products are on the production line, you reduce operating costs, cut service expense in the field—and safeguard the good will of your customers. Used in G-E refrigerator production for more than two years, the Type M detector uses helium as the tracer. The detector is so sensitive that it can detect one part of helium in 200,000 parts of air. Write for GEC-336.

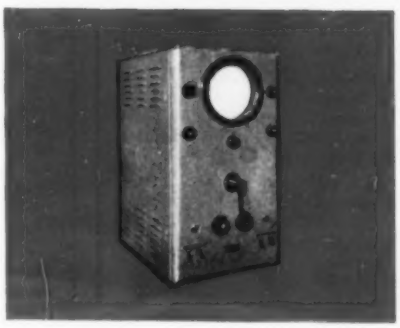


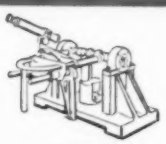
To Detect Insulation and Winding Faults Quickly

—use the G-E winding-insulation tester

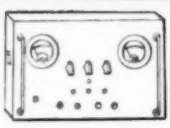
You can speed up production-line testing of motors, transformers, and generators by using the G-E winding-insulation tester. At one G-E plant, for example, more than 4000 motors a week are tested with one device.

Less than one minute is required for a complete test, which includes resistance, impedance, turn-balance, and complete high-potential tests. The operator can determine the nature of defects by the wave shapes of the oscillograms on the screen of the tester. Write for GEC-321.

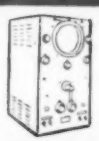




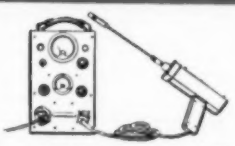
Materials Testing



Chemical Analysis



Insulation Tester



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Vibration and Sound

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TOOL and DIE USERS!

Pangborn "Hydro-Finish" Can Help You...

It improves surface finish, removes oxide scale, increases tool and die life through proper maintenance. Hydro-Finish is the new versatile impact blasting process that uses a fine mesh abrasive suspended in water and holds tolerances to .0001 inches.

In the Tool Room, Hydro-Finish simplifies the manufacture and maintenance of tools, dies and molds. It reduces usual costly handwork and produces a surface virtually free from directional grinding lines.

In the Production Line, Hydro-Finish eliminates many tedious finishing operations. It reduces cost and time involved in buffing. It improves fatigue life of the metal parts it finishes. It cuts many manufacturing costs.

It can be used for surface finishing, lubrication control, removing discoloration, preparing surfaces for plating, finishing threaded sections, plus many other uses.

Find out today how Hydro-Finish can help you.
Write for Bulletin 1490 to PANGBORN CORPORATION, 1204 Pangborn Blvd., Hagerstown, Md.

PANGBORNITE
The best abrasive for all liquid blasting needs.
Available in many mesh sizes.

Look to Pangborn for all the latest developments in Blast Cleaning and Dust Control Equipment.

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BLAST CLEANS CHEAPER with the right equipment for every job

Some Properties of Uranium

(Continued from p. 386)

reaction is triggered off and a lump of uranium results. These are small-scale operations compared with running a blast furnace, but nevertheless they were able to produce small quantities of uranium. You are also faced with the problem of a container that will hold the active metal and not react with it, or even not contaminate it.

Having obtained particles of the metal, there are several ways of consolidating it. In general, the results of powder metallurgy are not too satisfactory. It is difficult to obtain 100% density, and the strength and ductility are lower than that of a solid metal. Solid pieces of uranium so produced were not satisfactory for piles; some impurities apparently crept in and made the slugs unsatisfactory. Only by melting the powdered uranium was satisfactory material obtained.

The first problem in melting is the container; then there is the problem of atmosphere. The simplest "atmosphere" usually is a vacuum, but inert atmospheres also are satisfactory.

When we first started to work uranium, very little was known about it except that it burns very readily and is supposed to be quite poisonous. When we decided to forge some of it we noticed that the metal was hotter than the furnace, due to oxidation. Under the forge hammer it fell apart. Uranium should be worked in the alpha phase (stable at room temperature) but heated as close to the beta phase as possible. Later, rods of uranium were rolled and extruded.

The crystalline structure of uranium at room temperature is orthorhombic (which is rather uncommon among metals) and results in anisotropy of physical properties and a fairly low ductility. Preferred orientation results in thermal conductivity, for example, which is quite different in one direction as compared to another. The same thing applies to fabricated beryllium.

The coefficient of thermal expansion for uranium was reported at values between 3 and 26×10^{-6} per °C. Its three coefficients of expansion in the three axial directions are $+28 \times 10^{-6}$, -1.4×10^{-6}, and $+22 \times 10^{-6}$ per °C.

Uranium work hardens very appreciably. In a piece of pure, soft

(Continued on p. 392)

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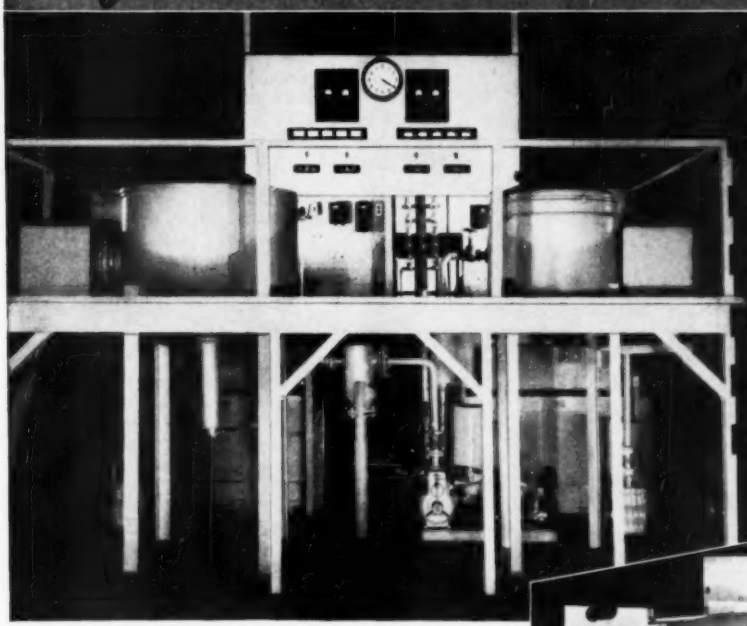

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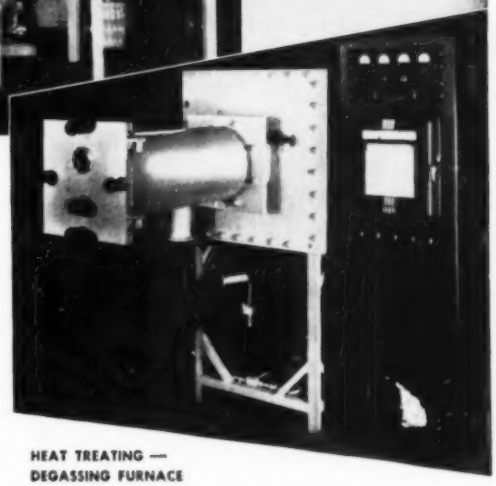

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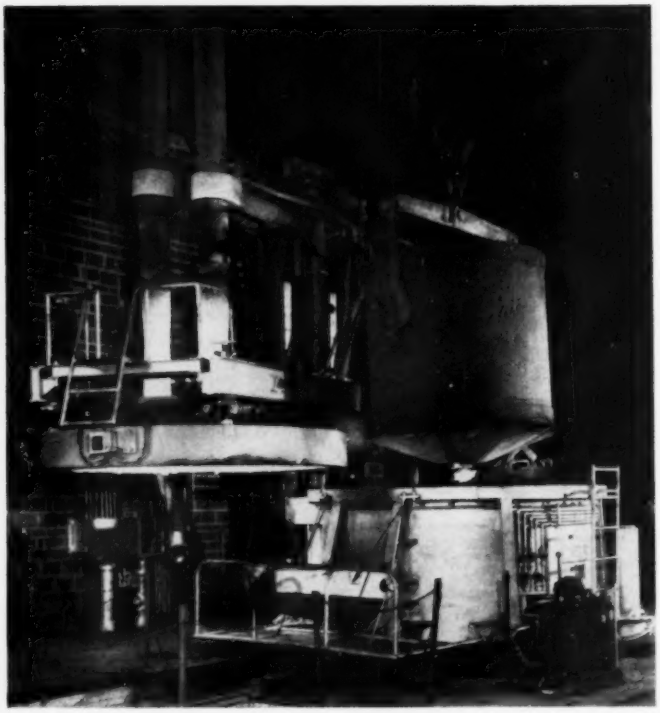

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Uranium

(Starts on p. 386)

uranium, the tensile strength will be about 30,000 to 50,000 psi., but after sufficient cold working the tensile strength may be as high as 200,000 psi. Other properties like hardness, strength, electrical conductivity, and probably thermal conductivity are modified by cold working, and the return of these properties to their normal values takes place at different temperatures which cannot be specified precisely.

A thorough study of the annealing of uranium has not been made, but process annealing is around 400 to 500° C. (750 to 925° F.).

Corrosion Resistance — Uranium is a very active metal. The oxide is probably more stable than aluminum oxide, but it does not form a protective film. At room temperature, uranium is quite stable, but even at 100° C. it will burn readily; at higher temperatures, it burns rapidly. Likewise, uranium is corroded readily by water.

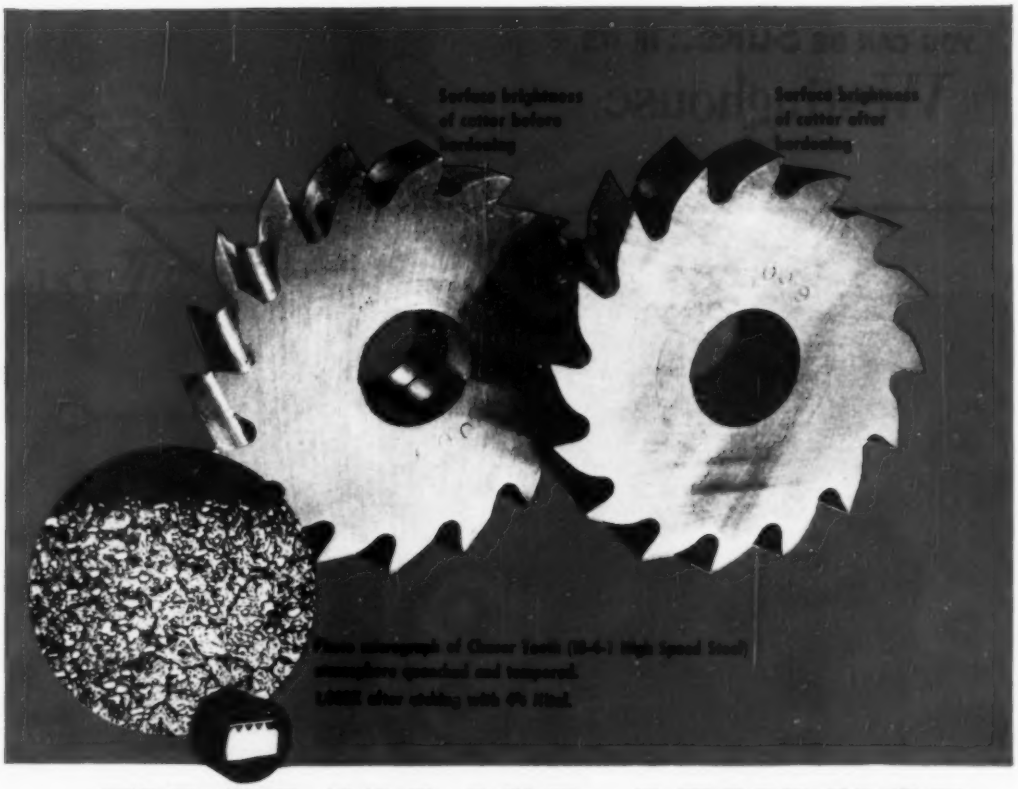
About 20 binary phase diagrams have been worked out for uranium, not only with common elements but also with rare elements that have certain alloying virtues.

Uranium has three crystalline phases. At room temperature and up to 660° C. (1220° F.) the crystal structure is orthorhombic. Beta uranium exists between 660 and 770° C. (1220 and 1420° F.); it has a very complex crystal structure. Above 770° C. there is another form which is body-centered cubic. Molybdenum is one alloying element that preserves this gamma phase of uranium at room temperature.

For use in nuclear reactors, the purity of uranium must be very high. Boron and cadmium are particularly undesirable, because they absorb neutrons. The best method of keeping impurities out is to avoid all possible contamination once the pure oxide has been obtained.

Quantitative analyses prove the absence of contamination, but no two analytical laboratories in this country can agree on beryllium. There are a number of elements they cannot even determine accurately (like beryllium itself). Of course, when you start worrying about parts per million, accurate analysis is quite a problem. One part per million is still a lot of atoms, probably 10^{17} atoms per cu. cm., but that is not many atoms for a chemist.

(Continued on p. 399)



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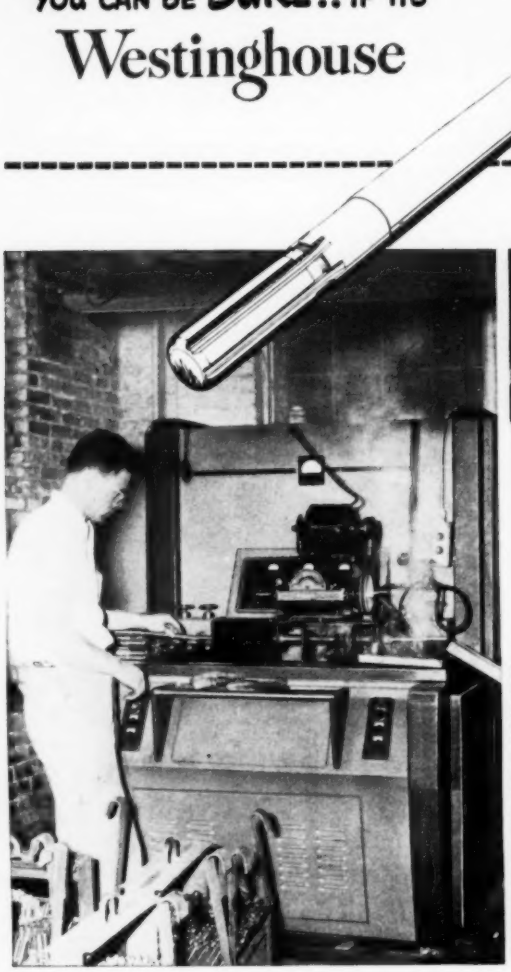
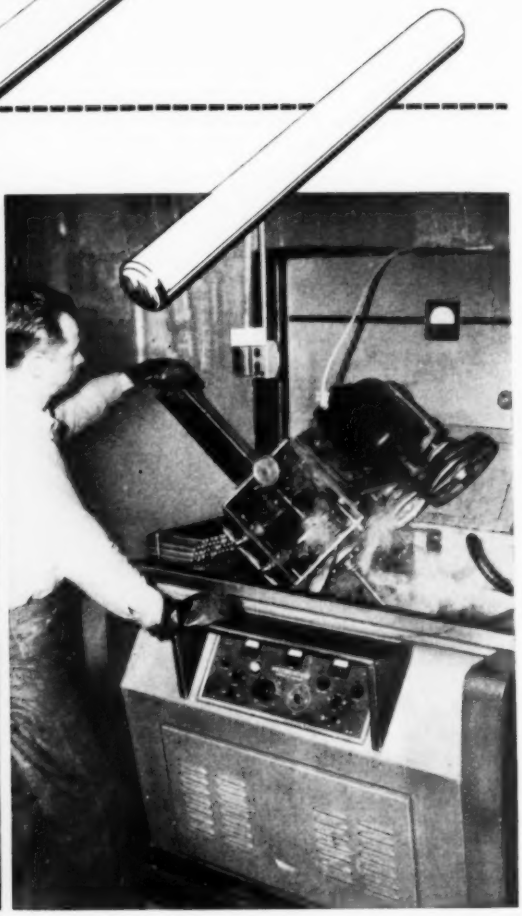


Spline Shaft Hardening at Maytag Company plant, Newton, Iowa. Diameter, .75". Length over-all, 8.5". Length of spline, 2". Steel, C-1144. Surface hardness, 57-60 Rc. Case depth, .027"-.035". Equipment, Westinghouse 20-kw RF Generator, Type C. Production, 580 per hour.



Straight Shaft Hardening with Westinghouse 20-kw RF Generator, Type B, at Maytag Company. Diameter, .685". Length over-all, 6.75". Steel, C-1144. Surface hardness, 57-60 Rc. Case depth, .027"-.035". Production, 600 per hour.

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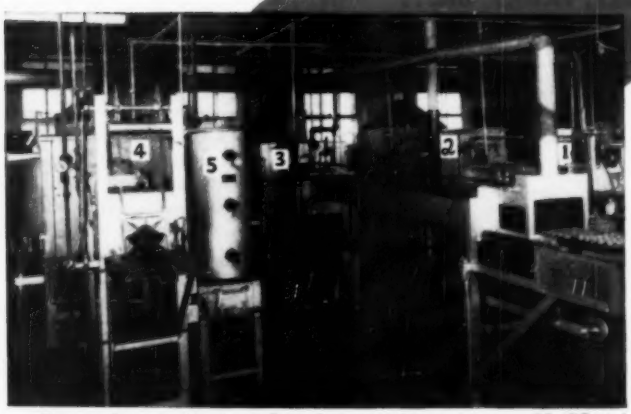

Shown above in Merriman Bros. heat treating room are: #1, "Certain Curtain" LA-210 Pusher Furnace (2100°F); #2, "Certain Curtain" BA-46 Pusher Furnace (2500°F); #3, "Certain Curtain" LAC-212 Conveyor Furnace (2100°F); #4, "Certain Curtain" BA-456 Pusher Furnace (2500°F); #5, Hayes IG Atmosphere Generator.

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Both high temperature zone and water jacketed cooling tunnel have complete atmosphere protection.

Atmosphere may be hydrogen, combusted gas, nitrogen, dissociated ammonia, etc.

Atmosphere generating equipment may be Hayes Combusted Gas Generator or AD Ammonia Dissociator.

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Representatives in Principal Cities

Uranium

(Starts on p. 386)

Analysis of beryllium and thorium for oxygen is almost out of the question because there is no way of obtaining elemental or molecular oxygen from them. Spectrographic methods were extensively used for analyses, but here again they begin to hit bottom in the region of 10^{17} atoms per cu.cm. Calorimetric methods are more sensitive than spectrographic.

References on Slack Quenching

(see p. 361)

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6. "A Statistical Study of the Variables Affecting the Mechanical Properties of Cast Steel", by J. B. Caine, *Steel Foundry Facts*, No. 53, December 1945.

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Life has been good to us and the friendships which mature through the years add depth and fine human values to the stimulation of wrestling new problems and crossing once distant technical horizons.

For more than two years we've been "out of circulation", have called on no customers, missed all A.S.M. meetings and outings, — and really *missed* them. We've been working close to a 16-hour day and enjoying it. The work has been fruitful beyond our hopes, as a search for truth frequently is.

In June 1947, after several months of preparation, and nearly five years of specialized researches, I undertook the direction of what is believed to be the most thorough and best facilitated research and development program ever undertaken on casting fundamentals. Factors that control the structure, metallurgical integrity, cleanliness and physical properties of high alloy and alloy steel castings have, themselves, never been controlled. Those that were known have not been understood.

This Research and Development Project: — non-profit — was sponsored by the U.S. Navy with the Bureau of Ships and the Bureau of Aeronautics jointly participating and, because of space, special equipment and liaison with a great university, was principally carried on in Champaign, Ill., with supplementary work at Boston. Some General Alloys' personnel participated with Alloy Engineering and Casting Company staff and with a diversified group of Engineers, Metallurgists and Technicians assembled for the Project.

To facilitate this work, highly specialized and technically advanced equipment was designed and built on the Project to practical operating scale. Special laboratories were equipped with facilities never before assembled in a foundry. Precedents were ignored. Many related, and heretofore unrelated, arts, techniques, sciences and materials were explored and evaluated.

In more than thirty years' experience in design, metallurgy and the engineering application of casting techniques aimed at control of fatigue resistance and ultimate life of cast complex alloys, — in diverse forms for severe services, — we became *profoundly conscious of our ignorance.*

Having founded the World's first organization devoted exclusively to the engineering and casting of heat and corrosion resistant castings (and forging and rolling of these in specialized applications), we were guided by no printed art or technology. Nothing was taught in the technical skills about these materials. (Currently there is very little taught, most of which is dubious.) All our lives we have encountered obstacles, most of which evolved from "short-circuits" between human ears, were atrophied into "precedent" and were ultimately resolved by "common sense" uncommonly applied.

We thought many of our limitations were personal or organizational. Our war activities gave us a broad view of contemporary foundry activities from which we gleaned little, except on mechanized production. A few individuals, like the late Peter Blackwood, provided education and inspiration. Since, we have striven mightily to evaluate our non-exclusive ignorance. Much of this "known wrong" began with a misconception of most casting fundamentals, obscured by the absence of controls, without which definite knowledge was unobtainable.

The urgent need in National Defense for jet and gas turbine engines, their actual potential expansion, and the coming implementation of Atomic Power, makes it imperative that:

(A) We advance our knowledge of designing, producing and employing heat and corrosion resisting materials.

(B) That these include Alloys, Ceramics, Cermets, Ceremels, Oxymets, Metalaminates, etc.

This new field has produced some little new technology. A stop-off exploitation of dental casting processes to the temporary exclusion of U.S. pre-war experience in high temperature materials and design is at last being metallurgically and mechanically rationalized. Some good work is emerging and a further shake-down is underway. More knowledge and less "experts" will emerge.

To date we have been too busy to seek commercial outlets to apply the broadly applicable findings of our Research and Development work. This work transcends the alloy casting field and will find many applications in the improvement of ferrous and non-ferrous castings, in structure, cleanliness and dimensional and surface precision heretofore unknown. Higher production at lower cost can result.

Such details of this Project as are "unclassified" will be released, subject to Navy approval, by the U.S. Technical Press, whose interest and cooperation have been most gratifying.

Eighteen editors and representatives of almost all Technical Publications covering this field, and more than fifty leading industrial concerns, have sent executives, engineers and metallurgists on Navy approved visits to the Project. Publication of details, as released with Navy approval, will appear in the Technical Press.

M. P. Readers have learned that grain size, in most as-cast materials, is almost directly proportional to fatigue life and has great effect on physical properties and corrosion resistance. You will be glad to know that casting grain size specifications (reducing the present range of "spread" by about 90%) can now be written for exacting requirements and will soon be common.

Some readers will appreciate the great satisfaction we have obtained in digging for, — and finding, — many answers to questions which have heretofore been unanswered. I regret the loss of my usual business contacts and visits with friends during the past two years, in compensation for which I can show but a minute reduction of a truly colossal ignorance.

To the Vision and Foresight which has guided Navy sponsorship of Research and Development Projects in Naval Laboratories, universities and in industry, can be credited many benefits to industry and the public, beyond the goals of technical excellence, economically applied, to Materiel for defense. Inspired by such Leadership and Support, we consider the past two years of our life have been usefully spent.

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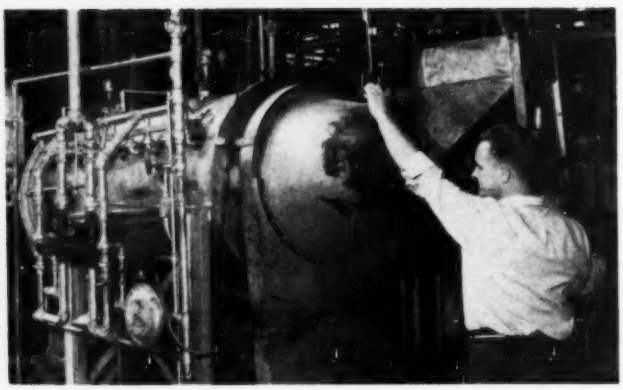

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188	338	750	1350
200	350	800	1400
213	363	850	1450
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238	388	950	1550
250	400	1000	1600
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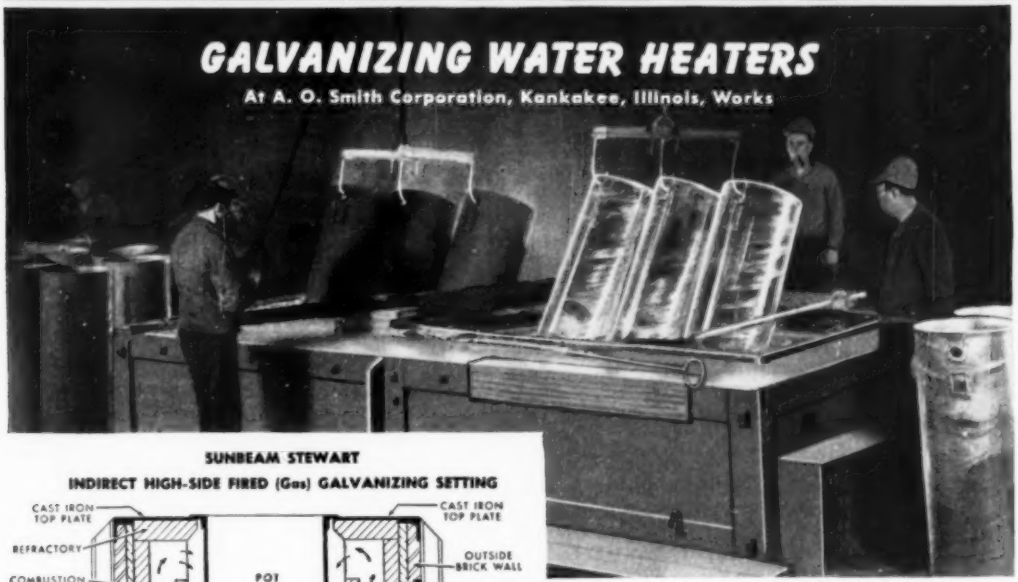

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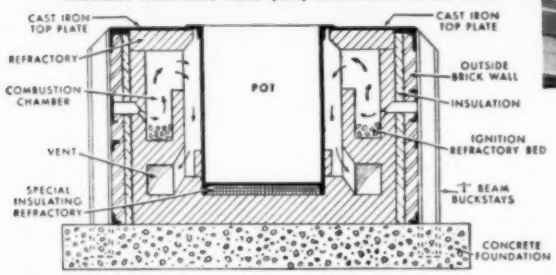

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3. **MAXIMUM PRODUCTION RATE**
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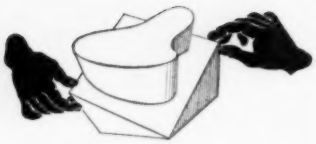

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High-Strength Aluminum

(References to article, p. 331)

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(Continued on p. 406)

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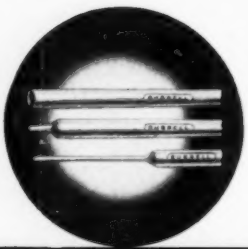

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Strong Aluminum

(Continued from p. 404)

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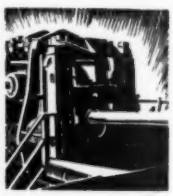

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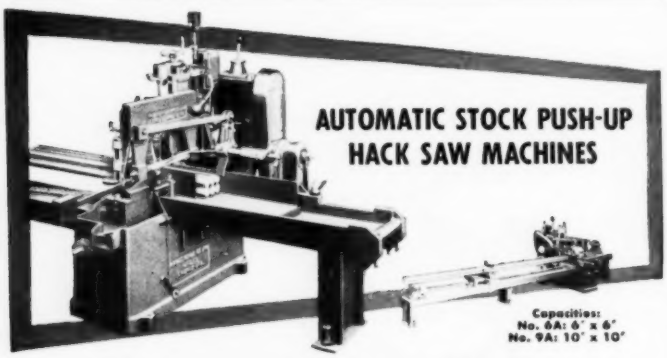

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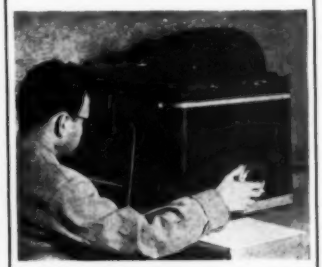

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Monoclinic, tetragonal, cubic, trigonal

PHYSICAL AND THERMAL PROPERTIES

Melting point	2675° ± 20°
Molecular volume	21.50
Heat of formation	264K cals/mol
Specific Gravity	5.5-6.0
Index of refraction	2.13-2.21+
Moh's hardness	6.5
Mean specific heat (20°-1000°C)	0.16
Thermal conductivity . app. 0.0089 cal/cm²/cm/°C/sec.	
Thermal expansion (mean reversible 20°-1000°)	6.6x10-⁶/°C
Coeff. of expansion (fused zirconia)	0.00000084
Compressive strength . . . . 20°C	298,680 psi
500°C	237,570 psi
1000°C	170,680 psi
1500°C	2,840 psi

ELECTRICAL PROPERTIES

Resistivity ohm-cm at . . . . 340°C	$2.1x10^6$
700°C	$2.3x10^4$
1200°C	$1.2x10^3$ ohm/cm³
Dielectric Constant	20.

Because of these properties, ZrO_2 is used to advantage in high temperature cements and ramming mixes and in precision casting mold facings. Various other TAM Zirconium Oxides such as Opax, Hy Opax, Treopax, Treopax 5 and Z, Zirox 8 and C. P. Zirconium Oxide are utilized in large quantities as opacifiers of ceramic glazes, as mill addition opacifiers for porcelain enamels and as optical glass and marble polishing media.

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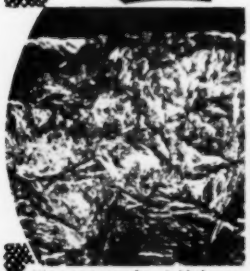
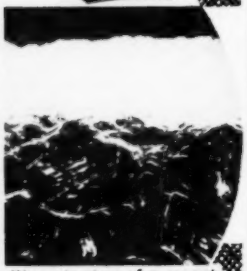


Micro-structure of a nitrided case produced by an improved nitriding process* which produces a surface with a minimum of "white layer".



Micro-structure of a normal nitrided case showing the white surface layer which generally must be removed by grinding or lapping.

AND REDUCES FINISHING COSTS OF THESE

A new special nitriding procedure, developed by Nitralloy, substantially reduces—and in many cases eliminates—grinding, or other finishing costs. The new method produces a surface with a minimum of white layer, a surface ideal for wear resistance, a surface which may require no finishing whatever, and the hardest metallic surface known.

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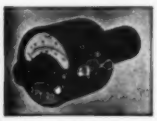

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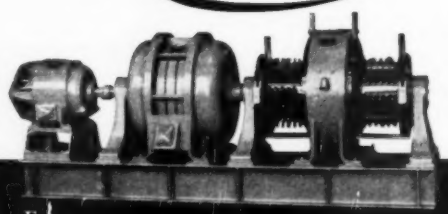

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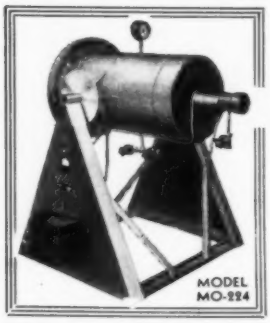

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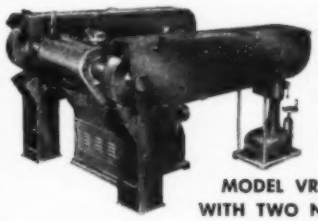

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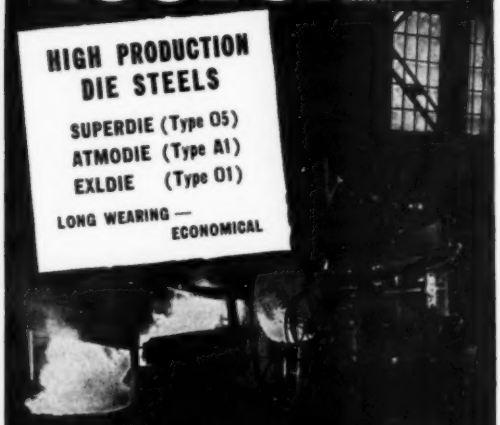

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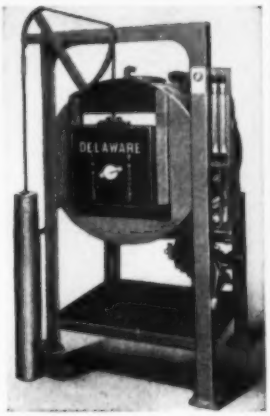

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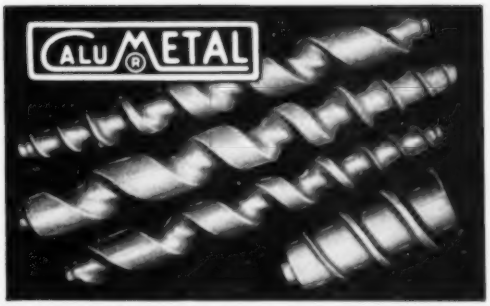

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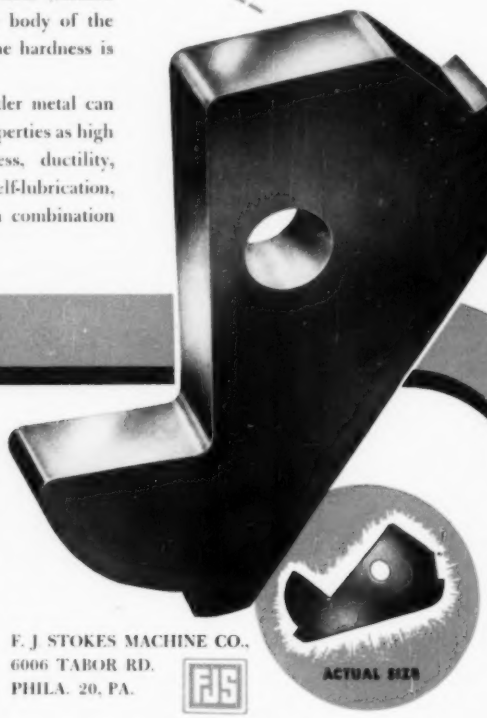

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